Radiological Health Data and Reports

VOLUME 12, NUMBER 7

JULY 1971

(Pages 363-404)

ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 7, July 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Environmental Protection Agency
Atomic Energy Commission

CONTENTS

CONTENTS—continued

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

Dr. Joseph A. Lieberman
Deputy Assistant Administrator
for Radiation Programs
Office of Radiation Programs

Address correspondence to the Editor, *Radiological Health Data and Reports*, Office of Radiation Programs, Parklawn 18B-40, Washington, D.C. 20460.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Reports

Evaluation of Television Contribution to the Annual Genetically Significant Radiation Dose of the Population

X-Radiation Ad Hoc Committee, Electronic Industries Association[1]

The X-Radiation Ad Hoc Committee of the Electronic Industries Association has used data from a U.S. Public Health Service survey of color television receivers in the Washington, D.C. area to estimate the annual genetically significant x-radiation dose to the U.S. population from television usage. Using these data and various assumptions, the annual genetically significant dose was estimated by the committee to be 0.5 mrem.

In a recent study, the X-Radiation Ad Hoc Committee, Electronic Industries Association, used U.S. Public Health Service (PHS) survey data to estimate the annual genetically significant x-radiation dose to the U.S. population due to television usage.

The primary purpose of this study was to determine, to the extent possible, whether the dose to the U.S. population due to television usage in early 1968 exceeded the objective established by the National Council on Radiation Protection and Measurements. The results of this study along with the study methods are reviewed in this paper.

Also included in this paper is a current appraisal of steps which have been or are being taken to further limit x radiation from television sets.

The objective of the National Committee on Radiation Protection and Measurements

In 1960 the National Committee[2] on Radiation Protection and Measurements (NCRP) published recommendations with regard to the maximum permissible x-radiation dose from television receivers. The position adopted by the NCRP was published in *Radiology* in July 1960 along with information on the objective of this organization (*1*).

In an interim statement approved on February 23, 1968, the NCRP reaffirmed its earlier standard. In this statement, the NCRP objective was restated as follows:

"The judgement of the NCRP is that the use of television receivers in the home should not contribute to the annual genetically significant dose to the population in excess of about 5% of the average dose from natural background radiation (about 120 mrem)."

Since two terms used in the NCRP statement may be unfamiliar, some comments are in order.

Annual genetically significant dose to the population

The "annual genetically significant dose to the population" is a measure of the genetic significance of the yearly dose received by the population's reproductive organs (gonads). To calculate this dose, one must consider the gonad dose and the future number of children expected by each member of the population (table 1).

Natural background radiation

Natural background radiation consists of a broad spectrum of ionizing radiation, both electromagnetic and particulate. Its distinguishing characteristics are that the entire population of the world is exposed and the exposure rate varies considerably from place to place with geological conditions, altitude, and latitude.

Sources of natural background radiation can be generally grouped into sources that are external to the body and sources that are internal to the body.

---

[1] Study team members are Morris Broyles, GE; Orville Neely, Motorola (now with MGA); Roger Slinkman, Sylvania; and Charles Thierfelder, RCA.

[2] Now council.

Table 1. Average number of expected children[a]

Age	Population (percent)	Sex (percent)	Average expected children
0-14 years:			
Male	15.8	32.1	3.29
Female	15.4	30.1	3.16
15-44 years:			
Male	19.4	39.4	1.94
Female	20.1	39.6	1.5
45 years and older:			
Male	14.0	28.4	.0242
Female	15.3	30.2	.0014

[a] Taken from 1960 U.S. Census Bureau data.

Sources that are external include cosmic rays and radioisotopes found in the crust and atmosphere of the earth. Cosmic rays produce a gonadal dose at sea level of the order of 30 millirem per year. The dose rate at a height of 3,000 meters is approximately three times that at sea level.

Radionuclides are found in greatest concentration in various types of rocks and secondarily, in soil, water, air, and food. Radionuclides external to the body contribute approximately 70 millirem per year to the gonad dose in most locations. This dose may be higher, up to 830 millirem per year in certain parts of India where radionuclide concentrations are high in the rock formations and soil.

Sources that are internal consist of radiation from isotopes in the cells of the body and those taken in food and water. The primary internal radiation contribution to the gonadal dose is from potassium-40, which is about 20 millirem per year.

The summation of these sources adds up to an average value of about 120 millirem per year and ranges up to a maximum of about 880 millirem per year.

The Washington, D.C. survey

In early 1968, the National Center for Radiological Health (NCRH) (now the Bureau of Radiological Health (BRH), with the active cooperation of the Electronic Industries Association, completed a limited survey of x-radiation emissions from color television receivers. The purpose of this survey was to obtain information on the x-ray emission of television receivers of all manufacturers included in a sample of color television receivers in use in the homes of PHS employees in the Washington, D.C. area. In all, 1,124 color television sets of a variety of brand names and models from 21 domestic and five foreign manufacturers were included in the survey.

A report of the survey was published on March 12, 1968, by the Technical Services Branch, NCRH (*2*). The results given in that report are applicable to the sample of color television receivers in the Washington Metropolitan Area and may not necessarily be applicable to color television receivers in the rest of the country.

In the Washington, D.C. survey, x-radiation measurements were made at the point, 5 cm from each television receiver surface where maximum emissions were detected. Therefore, the data recorded for each set included six maximum measurements, one for each of the six surfaces of the set. Additionally, data were recorded when the receiver was operated with the user controls set to three positions as follows:

Position A	User controls set to positions customarily used when viewing.
Position B	Same as Position A except brightness control was set to maximum brightness position.
Position C	Same as Position A except brightness control was set to minimum brightness position.

The Washington, D.C. survey report noted that x-radiation emissions were not detected from any surface of 856 of the 1,124 sets surveyed (table 2). Additionally, x-radiation emissions were not detected from some of the surfaces of the other 268 sets. Since it is possible that instrumentation limitations prevented the detection and measurement of very low levels of x-radiation emission

Table 2. Distribution of color television receivers by the x-radiation exposure rate

X-radiation exposure rate (mR/h)	Number of receivers in range
<0.040	856
.040-<0.075	52
.075-< .125	38
.125-< .25	68
.25 -< .50	44
.50 -< 1.00	26
1.00 -< 2.00	23
2.00 -< 3.75	5
3.75 -< 7.50	5
7.50 -<12.50	5
≥12.50	2
Total sets	1,124

from some of these surfaces, the assumption was made for this report that there were emissions of 0.02 mR/h from all surfaces shown in the data as having emission of "less than 0.04 mR/h" (believed to be a very conservative assumption).

The Stoms' instruments used in the survey were designed and constructed by the NCRH expressly for the purpose of performing in-home measurements of x-radiation emissions from color television receivers. The radiation sensitive element of this instrument was an array of six Victoreen-type 1B85 Geiger-Mueller tubes.

For the purpose of the Washington survey, the survey instruments were calibrated with an x-radiation beam from a 6EF4 shunt regulator tube operated with 25 kilovolts between cathode and anode.

Using this calibration, 4,000 counts per minute were equated to 0.5 mR/h. As further experience was gained, it was found that an instrument utilizing a 1B85 Geiger-Mueller tube could not be used to reliably measure the varied x-radiation emission from television receivers unless each emission is analyzed for energy distribution and the instrument is calibrated for all radiation energies to be measured. Table 3 shows a calibration currently being used for a Stoms' instrument.

Table 3. Bureau of Radiological Health calibration for Storms survey instrument[a] (Instrument #41)

Voltage (keV)	K radiating element	0.5 mR/h equals	1.0 mR/h equals
22.2	Silver	8,000 counts/min.	16,000 counts/min.
25.3	Tin	9,500 counts/min.	20,000 counts/min.
26.4	Antimony	10,000 counts/min.	
32.2	Barium	13,000 counts/min.	
33.4	Lanthanum	13,000 counts/min.	
37.4	Neodymium	13,000 counts/min.	
40.1	Samarium	12,000 counts/min.	
43.0	Gadolinium	12,000 counts/min.	
46.0	Dysprosium	10,000 counts/min.	
49.1	Erbium	9,000 counts/min.	

[a] All conversion factors are ±20 percent or greater.

This new calibration would indicate that when measuring emissions from color picture tube faceplates, 8,000 to 13,000 counts per minute rather than 4,000 counts per minute would equate to 0.5 mR/h. In the course of this study, no attempt was made to use this new calibration even though to do so would lower many of the emission levels reported in the Washington, D.C. survey.

Limited information on viewing habits was obtained through discussions with household members while the survey measurements were being made. These data are recorded in table 4.

The x radiation from any single set surveyed will vary with time depending upon variations in line voltage, signal conditions, user control adjustments, service control adjustments, and the failure and repair of sets. Even though this variability of any single set is recognized, it is expected that the average emission from a large number of sets, such as those surveyed in Washington, D.C., will remain reasonably constant. Therefore, this variability will not prevent the use of these data for estimating the annual genetically significant dose to the population.

Calculation methods

The following methods are for calculation of radiation from point sources, picture tube face plate and annual genetically significant dose. In this calculation, exposure to the younger individuals is weighed most heavily (table 1).

The annual skin dose to members of families who owned the color television sets surveyed by the Public Health Service in Washington, D.C. may be calculated using the following formula:

1. For radiation from point sources:

$$\text{Skin exposure} = \frac{1}{N}\sum_{i=1}^{N}\left[X_i \frac{H}{8}\left(\frac{I}{D+I}\right)^2\right] = \frac{H}{8N}\left(\frac{I}{D+I}\right)^2 \sum_{i=1}^{N} X_i \quad \ldots(1)$$

Where: X_i = Radiation in "i^{th}" television set (thousand counts per minute) measured 2 inches from surface,
I = Point source to meter distance = point source to cabinet surface in inches plus 2 inches,
D = Distance from meter to viewer = cabinet surface to viewer in inches minus 2 inches,
N = Number of receivers in survey,
$1/8$ = Converts thousand counts per minute to mR/h,
H = Average number of color viewing hours per year per person, and
Skin exposure = Annual accumulation in mR.

Table 4. Household members by age, by normal viewing distance and hours per week viewing time

Viewing time by age groups (hours per week)	Number of persons by viewing distance						
	Under 4 feet	4–7 feet	8–11 feet	12–15 feet	16 feet or greater	Not indicated	Total
All ages: (years)	84	659	969	484	71	44	2,311
≤15	49	290	442	225	39	16	1,061
16–30	24	239	376	179	19	8	845
≥31	11	127	148	78	13	3	380
Not indicated	0	3	3	2	0	17	25
Under 15 years old:	48	280	150	39	6	24	547
≤15	22	100	53	10	5	8	198
16–30	18	104	64	25	1	7	219
≥31	8	74	33	4	0	1	120
Not indicated	0	2	0	0	0	8	10
15–44 years old:	23	232	497	255	30	12	1,049
≤15	16	123	242	134	14	7	536
16–30	5	78	189	79	8	1	360
≥31	2	30	65	42	8	2	149
Not indicated	0	1	1	0	0	2	4
45 years old and over:	13	147	322	190	35	8	715
≤15	11	67	147	81	20	1	327
16–30	1	57	123	75	10	0	266
≥31	1	23	50	32	5	0	111
Not indicated	0	0	2	2	0	7	11

2. For radiation through faceplate of picture tube:

$$\text{Skin exposure} = \frac{1}{N}\sum_{i=1}^{N}\left[X_i \frac{H}{8} K\right]$$

$$= \frac{HK}{8N}\sum_{i=1}^{N} X_i \qquad \ldots(2)$$

Where: K = Correction factor for distance = radiation at distance D divided by radiation measured 2 inches from safety panel.

3. For calculation of male and female gonadal dose:

The annual per capita gonad dose can be calculated from the average skin exposure by using correction factors K_M and K_F:

Where: K_M = Depth dose at male gonads/skin exposure,

K_F = Depth dose at female gonads/skin exposure.

4. For calculation of the genetically significant dose:

The equation for genetically significant dose from UNSCEAR (*3*) was used for calculation of the genetically significant dose.

$$D = \frac{\sum_J \sum_K (N^F_{JK} W^F_{JK} d^F_{JK} + N^M_{JK} W^M_{JK} d^M_{JK})}{\sum_K (N^F_K W^F_K + N^M_K W^M_K)} \qquad \ldots(3)$$

Where: D = Annual genetically significant dose,

N_{JK} = Annual number of individuals of age-class K, subjected to class J exposure,

N_K = Total number of individuals of age-in-class K,

[3]W_{JK} = Future average number of children expected by an exposed individual of age-in-class K subsequent to a class J exposure,

W_K = Future number of children expected by an average individual of age-in-class K,

d_{JK} = Gonad dose per class J exposure of an individual of age-in-class K, and

F and M = Denote "female" and "male" respectively.

[3] Since the radiation levels from television are quite low, the number of expected children will be the same for individuals after irradiation as it was before. Therefore, for the purposes of these calculations W_{JK} will be assumed to be the same as W_K.

Calculations

The annual genetically significant dose to the U.S. population was estimated in this report to be 1.9 mrem based on the assumptions that (1) the entire population (in all 59.8 million U.S. households) was exposed to color television sets like those measured in Washington, D.C. in early 1968 and (2) viewing habits of the U.S. population matched the viewing habits recorded in Washington, D.C. The assumptions and computer calculations used in estimating this dose are outlined below.

A. The annual genetically significant dose to viewers was estimated to be 1.8 mrem using the following data and assumptions and calculation methods detailed above.

1. Emissions are those recorded in the Washington, D.C. survey from the fronts of color television receivers when user controls were set to positions customarily used when viewing receivers.

2. Data on viewing distance and viewing time were taken from table 4 and sex distribution of the U.S. population. The assumptions in tables 5 and 6 were used to simplify the calculations.

Table 5. Viewing distance assumptions

Viewing distance from table 4 (feet)	Viewing distance used in calculations (feet)
<4	3.0
4 to 7	5.5
8 to 11	9.5
12 to 15	13.5
≥16	16.0

Table 6. Viewing hours assumptions

Viewing hours per week from table 4	Viewing hours per week used in calculations
<15	10 (520 hours per year)
16–30	23 (1,196 hours per year)
≥31	40 (2,080 hours per year)

3. The following correction factors were used to calculate x-radiation levels at the various viewing distances. Since the x-radiation measurements were made 2 inches from the surface of the sets, it is necessary to calculate the actual viewer exposure based on distance from set. (The correction factors were supplied by Mr. Shih-Ping Wang, Zenith Radio Corporation.)

Viewing distance (feet)	Correction factor (percent)
3.0	22.0
5.5	8.9
9.5	3.1
13.5	1.6
16.0	1.1

4. The central axis depth dose factors used to calculate depth dose to the gonads from air dose were 72 percent for males and 11 percent for females. (These factors, based on measurements by Braestrup (*4*), were supplied by Robert D. Moseley, Jr., M.D., Professor and Chairman, Department of Radiology, the University of Chicago.)

B. The annual genetically significant dose to non-viewers was estimated to be about 5 percent of the dose to viewers.

The Washington, D.C. survey report did not provide information on exposure time or exposure distance for non-viewers. In order to estimate the dose to non-viewers, calculations were made using the following data and assumptions:

1. Emissions were those recorded in the Washington, D.C. survey from the back, top, bottom, and sides of color television sets when user controls were set to positions customarily used when viewing receivers.

2. Persons located at back, top, bottom or sides of operating sets were considered to be non-viewers. Average exposure times were assumed to be 100 to 200 hours per year.

3. Emissions from back, top, bottom and sides of receivers originate at point sources. The assumed distances from the point source to the surface of the receiver were as follows:

Back	4 to 8 inches
Top	6 to 12 inches
Bottom	6 to 12 inches
Left side	4 to 8 inches
Right side	4 to 8 inches

Typically, the distance from the receiver surface to receiver components which may be x-radiation sources is bracketed by the distances listed above.

4. The distance from the set surface to non-viewers was assumed to be 3 feet to 7 feet. These distances were chosen to bracket the most likely average distance between the set and non-viewers who are in the vicinity of operating receivers.

Using the data, assumptions, and calculation methods detailed above, the skin exposure of non-viewers of the color television sets surveyed in Washington, D.C. was calculated. It was found that the skin exposure of non-viewers was approximately 5 percent of the skin exposure to viewers. Using the same depth dose factors used for calculating dose to viewers, the annual genetically significant dose to non-viewers was estimated to be 0.1 mrem (5 percent of the dose to viewers).

C. By summing the above doses to viewers and non-viewers, the annual genetically significant dose to the U.S. population was estimated to be 1.9 mrem assuming the entire U.S. population was exposed to color television sets like those surveyed in Washington, D.C., and assuming the viewing habits of the U.S. population matched the viewing habits recorded in Washington, D.C.

The annual genetically significant dose to the U.S. population from radiation emanating from color and monochrome television in use in early 1968 was estimated to be 0.5 mrem based on the following assumptions and calculations.

At the time of the Washington, D.C. survey, there were in the United States 14.1 million color television households, 42.3 million monochrome television households, and 3.4 million non-television households. There were 5.7 percent of U.S. households without television, 23.7 percent with color television and 70.6 percent with monochrome television.

There appears to be general agreement that little, if any, x radiation is emitted from the monochrome television sets in use. Furthermore, the depth dose factor' for monochrome sets operating at lower tube voltages, is lower. In order to make a conservative estimate, the assumption was made that the annual genetically significant dose to residents in monochrome television households was 0.1 mrem or about 5 percent of the estimated dose of residents of color television households.

From the above data and assumptions, the annual genetically significant dose to the U.S. population is estimated to be 0.5 mrem. This dose is less than ½ of 1 percent of the average dose from natural background radiation (about 120 mrem) and is well within the maximum permissible dose from television receivers of 6 mrem recommended by the National Council on Radiation Protection and Measurements.

Current appraisal

There is evidence to indicate a downward trend in x-radiation emissions for color television receivers sold after 1964. The percentage of color television receivers included in the Washington, D.C. survey emitting 0.5 mR/h or more by years of purchase is shown in figure 1, and those sets emitting 0.25 mR/h or more by year of purchase are shown in figure 2.

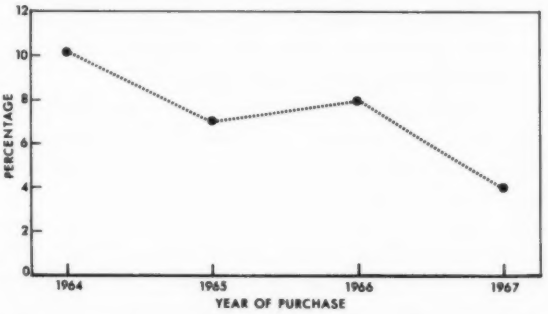

Figure 1. Percentage of color television receivers included in the Washington, D.C. survey emitting 0.5 mR/h or more, by year of purchase

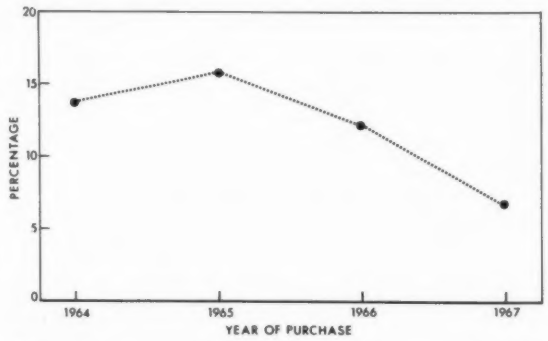

Figure 2. Percentage of color television receivers included in the Washington, D.C. survey emitting 0.25 mR/h or more, by year of purchase

"Electronic Industries Association's Ad Hoc Committee on X radiation from Television Receivers" has conducted five industry audits to monitor the trend in x-radiation emissions from color television receivers manufactured between 1964 and March 15, 1970. The number of color

Table 7. Color television receivers by x-radiation exposure rate and manufacturing date[a]

Reporting period	Number of receivers				
	X-radiation exposure rate (mR/h)				
	Background	>Background to <0.3	0.3–0.5	Over 0.5	Total
1964–June 1967	246	278	31	18	573
July 1967–February 1968	11,696	7,503	17	4	19,225
March 1968–April 1969	77,975	61,391	41	21	139,428
May 1969–September 1969	31,351	13,907	33	28	45,319
October 1969–March 1970	24,990	23,407	6	—	48,403

[a] The percent of color television receivers monitored emitting 0.3 mR/h or more has decreased from 8.5 percent in the 1964 to June 1967 manufacturing reporting period to 0.012 percent with no reading exceeding 0.5 mR/h in the October 1969 to March 15, 1970 manufacturing period.

television receivers by x-radiation exposure rate and manufacturing date are tabulated in table 7.

This downward trend in x-radiation exposure rate for television receivers is a consequence of the combined effort of the BRH, the television industry, and the Underwriters' Laboratories. In 1968 and 1969, the industry had developed improved electronic components, circuit design, radiation measuring and monitoring instrumentation, and manufacturing and control procedures to assure compliance with the NCRP recommendation and to meet the more stringent Federal standards which became effective on June 1, 1970.

Progress in this area is continuing. A major undertaking, which is presently underway, involves the design and production of a new family of picture tubes for use in color television. These tubes will incorporate glassware especially formulated to control x-radiation emission when picture tubes are subjected to extreme abnormal operating conditions. These new picture tubes, along with other advances will make possible industry compliance with the new, even more stringent Federal standards which became effective on June 1, 1971.

Conclusions

The judgment of the National Council on Radiation Protection and Measurements is that "the use of television receivers in the home should not contribute to the annual genetically significant dose of the population in excess of about 5 percent of the average dose from natural background radiation (about 120 millirem in a year)." This study of the Washington, D.C. survey data gives evidence that the annual genetically significant dose due to television usage in early 1968 was about 0.5 millirem, or less than ½ of 1 percent of the average dose from natural background radiation.

The Washington, D.C. survey data also provide evidence to indicate a downward trend in x-radiation emissions for color television receivers sold after 1964. A similar trend is shown in data collected by the Electronic Industries Association for color sets manufactured in the period, 1964 through March 15, 1970.

Acknowledgment

The authors are grateful to Mr. Robert H. Neill and other Bureau of Radiological Health, U.S. Public Health Service, staff members who provided assistance and consultation; to Mr. James Harrell, Motorola, Inc., who programmed and performed the computer calculations; and to Mr. Robert Donofrio, Sylvania Electric Products, Inc., who provided consultation.

Consultants

Mr. Carl B. Braestrup, F.A.C.R., Consulting Radiological Physicist, Lenox Hill Hospital, New York City, N.Y.

Dr. Robert D. Moseley, Jr., Professor and Chairman, Department of Radiology, University of Chicago, Chicago, Ill.

Dr. Harold O. Wyckoff, Chairman of the International Commission on Radiological Units and Measurements.

REFERENCES

(*1*) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. National Committee on Radiation Protection and Measurements. Radiology 173:122 (1960).

(*2*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH, TECHNICAL SERVICES BRANCH. A summary of the Washington, D. C. Metropolitan area survey of color television receivers. Radiol Health Data Rep 9:531–538 (October 1968).

(*3*) UNITED NATIONS SCIENTIFIC COMMITTEE. Report of the United Nations Scientific Committee on the effects of atomic radiation, Thirteenth Session, Supplement No. 17(A/3838) New York, N.Y. (1958).

(*4*) BRAESTRUP, C. P. and R. T. MOONEY. X-ray emission from television sets. Science 130:1071–1074 (October 23, 1959).

SECTION I. MILK AND FOOD

Milk Surveillance, March 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of

Figure 1. Milk sampling networks in the Western Hemisphere

both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2 σ), for these elements are 1.16 $\pm$ 0.08 g/liter for calcium and 1.51 $\pm$ 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, National, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium 89: High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation, table 2, also reflects whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine–131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance

Table 2. Concentrations of radionuclides in milk for March 1971 and 12-month period, April 1970 through March 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	NA	5	0	0	11	9
Alaska:	Palmer[c]	P	3	5	0	0	15	11
Ariz:	Phoenix[c]	P	NA	1	0	0	0	0
Ark:	Little Rock[c]	P	10	13	0	0	0	11
Calif:	Sacramento[c]	P	NA	2	0	0	0	0
	San Francisco[c]	P	NA	2	0	0	0	0
	Del Norte	P	7	16	0	0	0	11
	Fresno	P	0	2	0	0	0	0
	Humboldt	P	3	5	0	0	0	4
	Los Angeles	P	2	2	0	0	0	0
	Mendocino	P	2	3	0	0	0	1
	Sacramento	P	8	3	0	0	0	1
	San Diego	P	0	2	0	0	0	0
	Santa Clara	P	0	2	0	0	0	1
	Shasta	P	3	3	0	0	0	2
	Sonoma	P	2	3	0	0	0	1
Colo:	Denver[c]	P	NA	5	0	0	0	1
	West	R	(d)		NS	*1	NS	*1
	Northeast	R	(d)		NS	*0	NS	*0
	East	R	(d)		NS	*0	NS	*0
	Southeast	R	(d)		*0	*0	*0	*0
	South Central	R	(d)		*0	*0	*0	*0
	Southwest	R	(d)		*0	*0	*0	*3
	Northwest	R	(d)		NS	*0	NS	*0
Conn:	Hartford[c]	P	NA	8	0	0	16	12
	Central	P	7	7	0	0	12	15
Del:	Wilmington[c]	P	NA	9	0	0	0	8
D.C:	Washington[c]	P	NA	7	0	0	16	8
Fla:	Tampa[c]	P	6	5	0	0	47	51
	West	R	6	9	0	0	17	21
	North	R	4	10	0	0	24	27
	Northeast	R	8	6	0	0	29	36
	Central	R	8	6	0	0	28	49
	Tampa Bay area	P	8	6	0	0	48	50
	Southeast	P	8	7	0	1	74	80
Ga:	Atlanta[c]	P	NA	12	0	0	12	14
Hawaii:	Honolulu[c]	P	5	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	5	5	0	0	13	8
Ill:	Chicago[c]	P	6	7	0	0	16	11
Ind:	Indianapolis[c]	P	NA	8	0	0	0	7
	Northeast	P	10	10	0	0	15	13
	Southeast	P	9	11	0	0	10	10
	Central	P	8	9	0	5	10	10
	Southwest	P	10	12	0	0	0	9
	Northwest	P	11	11	0	0	10	13
Iowa:	Des Moines[c]	P	NA	6	0	0	0	3
	Iowa City	P	7	8	0 (2)	0	18 (2)	13
	Des Moines	P	6	8	0 (5)	0	12	11
	Spencer	P	5	5	0	0	17	8
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[c]	P	NA	8	0	0	0	3
	Coffeyville	P	8	9	0	2	11	4
	Dodge City	P	6	7	0	2	12	2
	Falls City	R	7	12	0	3	11	8
	Hays	P	8	12	10	2	10	8
	Kansas City	P	8	8	14	3	24	11
	Topeka	P	8	10	0	2	12	8
	Wichita	P	7	11	0	0	12	4
Ky:	Louisville[c]	P	NA	10	0	0	0	3
La:	New Orleans[c]	P	13	14	0	0	17	19
Maine:	Portland[c]	P	NA	10	0	0	19	21
Md:	Baltimore[c]	P	NA	8	0	0	11	7
Mass:	Boston[c]	P	8	10	0	0	19	22
Mich:	Detroit[c]	P	NA	8	0	0	18	10
	Grand Rapids[c]	P	NA	10	0	0	11	14
	Bay City	P	NA	7	*0	*0	20	13
	Charlevoix	P	NA	12	*0 (4)	1	17 (4)	15
	Detroit	P	NA	8	*0	*0	10	8
	Grand Rapids	P	NA	9	*0	*0	14	8
	Lansing	P	NA	9	*0 (2)	*0	15 (2)	14
	Marquette	P	11	13	*0 (3)	*0	20 (3)	22
	Monroe	P	6	6	*0 (3)	*0	9 (3)	3
	South Haven	P	8	8	*0 (4)	*0	4 (4)	5
Minn:	Minneapolis[c]	P	NA	10	0	0	13	12
	Bemidji	P	11	8	0	0	25	21
	Mankato	P	6	5	0	0	0	16
	Rochester	P	8	7	0	0	0	12
	Duluth	P	18	13	0	0	26	26
	Worthington	P	0	4	0	0	0	0
	Minneapolis	P	11	11	0	0	17	17

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for March 1971 and 12-month period, April 1970 through March 1971—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES: Continued								
	Fergus Falls	P	7	6	0	0	13	13
	Little Falls	P	17	12	0	0	20	34
Miss:	Jackson[c]	P	NA	12	0	0	0	9
Mo:	Kansas City[c]	P	NA	8	0	0	0	3
	St. Louis[c]	P	NA	9	0	0	0	4
Mont:	Helena[c]	P	NA	5	0	0	15	9
Nebr:	Omaha[c]	P	NA	4	0	0	0	1
Nev:	Las Vegas[c]	P	NA	3	0	0	0	0
N.H:	Manchester[c]	P	NA	9	0	0	18	21
N.J:	Trenton[c]	P	NA	7	0	0	15	11
N. Mex:	Albuquerque[c]	P	NA	3	0	0	0	0
N.Y:	Buffalo[c]	P	6	7	0	0	13	11
	New York City[c]	P	NA	10	0	0	16	18
	Syracuse[c]	P	NA	7	0	0	16	10
	Albany	P	9	8	0	0	*0	0
	Massena	P	8	8	0 (2)	0	22 (2)	25
	Newburg	P	5	8	0 (5)	0	*0 (5)	0
	New York City	P	9	10	0	0	*0	0
	Syracuse	P	6	4	0	0	0	0
N.C:	Charlotte[c]	P	NA	11	0	0	11	11
N.Dak:	Minot[c]	P	NA	9	0	0	11	11
Ohio:	Cincinnati[c]	P	NA	8	0	0	0	3
	Cleveland[c]	P	NA	9	0	0	0	12
Okla:	Oklahoma City[c]	P	NA	7	0	0	16	7
Oreg:	Portland[c]	P	0	5	0	0	0	4
	Baker	P	4	*0	*0	*0	22	9
	Coos Bay	P	4	3	*0	*0	*0	13
	Eugene	P	5	3	*0	*0	*0	1
	Medford	P	3	3	*0	*0	17	9
	Portland composite	P	10	6	*0	*0	*0	6
	Portland local	P	5	5	*0	*0	20	7
	Redmond	P	3	3	*0	*0	*0	*0
	Tillamook	R	NA	7	*0	*0	*0	17
Pa:	Philadelphia[c]	P	NA	9	0	0	11	7
	Pittsburgh[c]	P	NA	11	0	0	12	15
	Dauphin	P	7	7	0	2	21	12
	Erie	P	9	10	0	0	32	25
	Philadelphia	P	15	9	0	0	9	15
	Pittsburgh	P	13	12	0	1	21	20
R.I:	Providence[c]	P	NA	9	0	0	19	19
S.C:	Charleston[c]	P	8	10	0	1	15	17
S.Dak:	Rapid City[c]	P	7	7	0 (2)	0	6 (2)	5
Tenn:	Chattanooga[c]	P	NA	10	0	0	11	9
	Memphis[c]	P	NA	9	0	0	0	7
	Chattanooga	P	9	9	0	0	18	15
	Clinton	P	9	11	0 (2)	0	20	16
	Fayetteville	P	NS	12	NS	0	NS	14
	Knoxville	P	6	7	0 (2)	0	21	13
	Nashville	P	6	6	0	0	25	11
Tex:	Austin[c]	P	NA	2	0	0	0	2
	Dallas[c]	P	NA	7	0	0	14	6
	Amarillo	R	3	4	NS	NA	0	5
	Corpus Christi	R	NS	3	NS	0	0	0
	El Paso	R	NS	3	NS	NA	0	2
	Fort Worth	R	NS	5	NS	NA	0	0
	Harlingen	R	2	2	NS	NA	0	0
	Houston	R	NS	6	NS	NA	0	14
	Lubbock	R	NS	3	NS	NA	0	0
	Midland	R	NS	2	NS	NA	0	0
	San Antonio	R	3	3	NS	NA	0	0
	Texarkana	R	NS	8	NS	NA	0	0
	Tyler	R	10	13	NS	NA	10	13
	Uvalde	R	NS	2	NS	NA	0	0
	Wichita Falls	R	NS	8	NS	NA	0	0
Utah:	Salt Lake City[c]	P	0	4	0	0	0	11
Vt:	Burlington[c]	P	NA	8	0	0	16	15
Va:	Norfolk[c]	P	NA	9	0	0	0	8
Wash:	Seattle[c]	P	NA	5	0	0	0	3
	Spokane[c]	P	NA	6	0	0	0	1
	Benton County	R	3	1	0	0	0	2
	Franklin County	R	NS	3	NS	0	NS	3
	Sandpoint, Idaho	R	13	11	0	0	18	22
	Skagit County	R	6	6	0	0	11	11
W.Va:	Charleston[c]	P	NA	8	0	0	12	6
Wisc:	Milwaukee[c]	P	NA	6	0	0	20	13
Wyo:	Laramie[c]	P	NA	5	0	0	0	1
CANADA:								
Alberta:	Calgary	P	7	7	(d)		16	17
	Edmonton	P	7	7	(d)		24	21

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for March 1971 and 12-month period, April 1970 through March 1971—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA: Continued							
British Columbia: Vancouver	P	7	9	[d]		17	24
Manitoba: Winnipeg	P	7	7	[d]		21	24
New Brunswick: Fredericton	P	11	12	[d]		28	24
Newfoundland: St. John's	P	12	17	[d]		18	33
Nova Scotia: Halifax	P	9	11	[d]		24	21
Ontario: Ottawa	P	13	14	[d]		36	34
Sault Ste. Marie	P	11	12	[d]		26	25
Thunder Bay	P	6	6	[d]		16	15
Toronto	P	5	4	[d]		17	11
Windsor	P	5	5	[d]		14	11
Quebec: Montreal	P	7	7	[d]		21	19
Quebec	P	9	9	[d]		36	29
Saskatchewan: Regina	P	7	7	[d]		17	14
Saskatoon	P	7	9	[d]		17	17
CENTRAL AND SOUTH AMERICA:							
Colombia: Bogota	P	2	1	0	0	0	0
Chile: Santiago	P	0	0	0	0	0	0
Ecuador: Guayaquil	P	0	0	0	0	0	0
Jamaica: Mandeville	P	NS	5	NS	0	NS	71
Venezuela: Caracas	P	0	1	0	0	0	0
Canal Zone: Cristobal[c]	P	NA	1	0	0	0	9
Puerto Rico: San Juan[c]	P	NA	4	0	0	12	8
PMN network average[f]		6	7	0	0	8	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado–25 pCi/liter; Michigan–14 pCi/liter; Oregon–15 pCi/liter
Cesium-137: Colorado–25 pCi/liter; New York–20 pCi/liter; Oregon–15 pCi/liter
Strontium-90: New York–3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

provided by the Federal Radiation Council for specific environment conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion

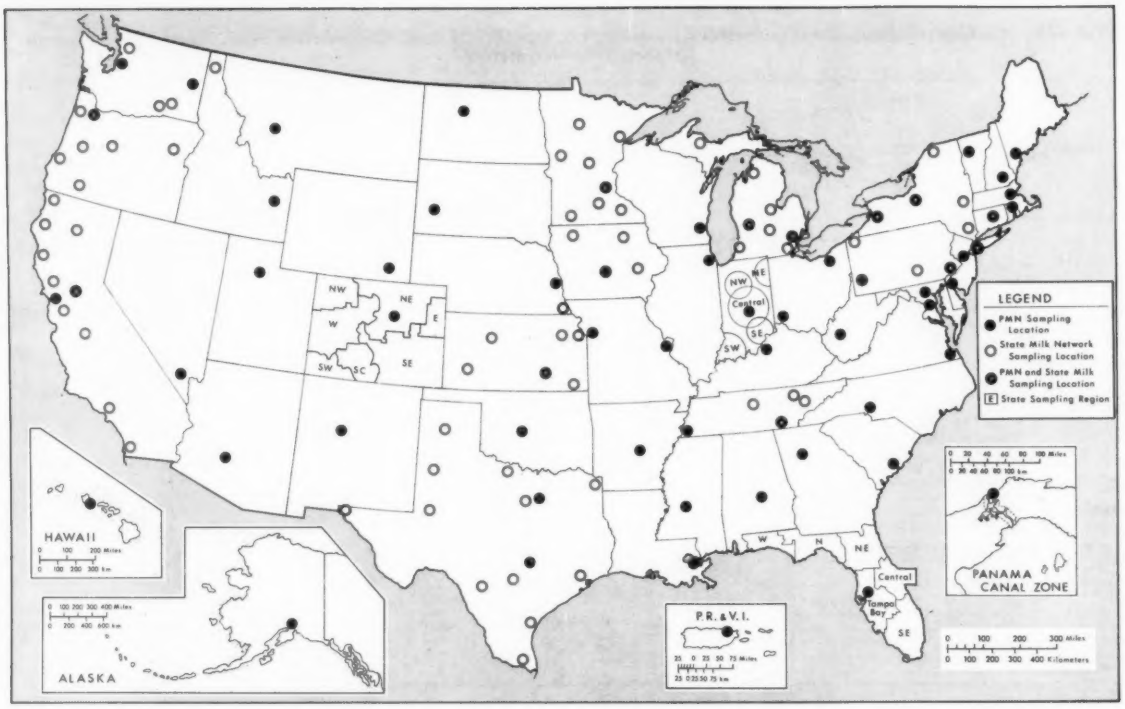

Figure 2. State and PMN milk sampling locations in the United States

for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for March 1971 and the 12-month period, April 1970 to March 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for March 1971 were below the respective practical reporting levels. The following station average reflects a sample in which strontium-89 was detected: California, Del Norte, 27 pCi/liter; Sacramento, 11 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 18 pCi/liter in the United States for March 1971, and the highest 12-month average was 16 pCi/liter (Del Norte, Calif. (State)) representing 8.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 74 pCi/liter in the United States for March 1971, and the highest 12-month average was 80 pCi/liter (Southeast Florida (State)), representing 2.2 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Kansas City, Kans. (State), 14 pCi/liter.

Acknowledgment

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engineering
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section Division of Health
Washington Department of Social and Health Services

REFERENCES

(*1*) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides is milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1959).

(*2*) U. S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT: Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) KNOWLES, F. Interlaboratory study of iodine-131, cesium-137, barium-140, strontium-89, and strontium-90 measurements in milk, May–July 1970, Technical experiment 70-MKAQ-1. Analytical Quality Control Service, Bureau of Radiological Health (September 1970).

(*6*) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621–627 (November 1967).

(*7*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

(*8*) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The cause of relatively high cesium-137 concentrations in Tampa, Florida, milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 in Total Diet and Milk	July–December 1970	May 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	October–December 1970 and Annual Summary 1970	May 1970
Strontium-90 in Tri-City Diets, *HASL*	January–December 1969	June 1970

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2–4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1967–1969	December 1970
Kansas	January–December 1969	September 1970
Minnesota	July–December 1969	May 1971
North Carolina	January–December 1967	May 1969
New York	January–June 1969	June 1970
Radiostrontium in Tap Water, *HASL*	January–June 1970	April 1971
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	July–December 1970	May 1971
Washington	July 1968–June 1969	February 1971

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintend of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Interstate Carrier Drinking Water Analysis Program, 1970

Office of Water Programs and Office of Radiation Programs, Environmental Protection Agency

The routine surveillance of finished drinking water from public drinking water supplies has been a project of a division [formerly the Bureau of Water Hygiene, Public Health Service (PHS)] of the Office of Water Programs of the Environmental Protection Agency (EPA) since 1960, in partial fulfillment of the requirements as set forth in Subpart J of the Interstate Quarantine Regulation (*1*) most commonly referred to as the Public Health Service Drinking Water Standards. The basic network for this activity is the approximately 665 water supplies (serving over half of the U.S. population with access to public water systems) which provide water for use by interstate carriers. Laboratory support is provided by the Northeastern Radiological Health Laboratory of the PHS, and the Eastern Environmental Radiation Laboratory and Western Environmental Research Laboratory of EPA. For the most part, samples were composited over a 14-day period, taking 90 milliliters, three times during the operating day; however, as indicated in table 1, many samples were also taken as a single grab sample. In many cases where a water system receives raw water from more than one source, the finished drinking water derived from each source has been examined.

The drinking water standards for radionuclides are conservative in their requirements so that the total intake of these nuclides from all sources is not likely to result in an intake greater than the guidance levels given by the Federal Radiation Council (*2*).

The standards provide for the approval of water supplies, based on their radionuclide content, when the water does not contain more than 3 pCi/liter of radium-226 or 10 pCi/liter of strontium-90. In the absence of strontium-90, and in the absence of alpha emitters, the water supply is acceptable when the gross beta concentration does not exceed 1,000 pCi/liter.

However, a water supply may be approved when the limits prescribed above are exceeded if it can be demonstrated by surveillance that the total intake of radioactivity from all sources is within the guidance for control action recommended by the Federal Radiation Council. When mixtures of radionuclides are present, the relative contribution of each radionuclide to the total intake of the individual should be considered when evaluating the exposure.

Table 1 provides the results of the radiological analyses and table 2 is a summary of the results.

REFERENCES

(*1*) DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE. Federal Register Rules and Regulations, Title 42, Public Health Chapter 1, Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards:2154–2155 (March 6, 1962).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (September 1961).

Previous coverage in Radiological Health Data and Reports:

Period	Issue
1961–1966	August 1968
1967–1969	December 1970

Table 1. Radiological analyses of Interstate Carrier water supplies, 1970[a]

Sampling location		Sampling periods	Gross alpha radioactivity		Gross beta radioactivity		^{226}Ra	^{90}Sr
			Dissolved	Suspended	Dissolved	Suspended		
Del:	Delaware City	10/7	0 (total)		3 (total)			
	Lewes	10/6	0 (total)		0 (total)			
	Wilmington	10/7	0 (total)		3 (total)			
Fla:	Hialeah (Preston Plant)	4/23–5/7	0	0	4	0		
	Hialeah (Hialeah Plant)	4/23–5/7	0	0	4	0		
	Miami	4/22–5/6	0	0	0	0		
Ill:	Cairo	6/1–6/22	0	0	5	0		
	Carbondale	11/9	0 (total)		8 (total)			
	Des Plaines	3/20	0	0	3	0		
	Franklin Park	9/15	0 (total)		4 (total)			
	Moline	11/4	0 (total)		9 (total)			
	Rosemont	9/15	0 (total)		3 (total)			
	Savanna	6/3	5	0	9	0	2.1	
	Schiller Park	4/3	0	0	4	0		
	Wood River	11/12	0 (total)		4 (total)			
Ind:	Logansport	5/31–6/4	0	0	6	0		
	Mt. Vernon	6/30	0 (total)		7 (total)			
	Washington	6/29	0 (total)		5 (total)			
La:	Baton Rouge	2/25	0	0	0	0		
Maine:	Portland	6/30–7/13	0 (total)		6 (total)			
Nebr:	Grand Island	11/11	17 (total)		14 (total)		1.4	0
	Scottsbluff	11/10	17 (total)		20 (total)		.3	0
N.J:	Elizabeth	8/26–9/8	0 (total)		4 (total)			
	Raritan	8/27–9/10	0 (total)		3 (total)			
	Wrightstown	9/1–9/14	0 (total)		4 (total)			
		9/15	0 (total)		5 (total)			
N.Y:	Latham	10/1–10/14	0 (total)		4 (total)			
	Troy	10/1–10/15	0 (total)		5 (total)			
Ohio:	Cleveland	10/6	0 (total)		6 (total)			
		10/7	0 (total)		7 (total)			
		10/8	0 (total)		5 (total)			
		10/9	0 (total)		6 (total)			
	Hamilton	9/1–9/9	0 (total)		3 (total)			
	Lorain	11/18	0 (total)		5 (total)			
	Vandalia	9/1–9/8	0 (total)		0 (total)			
	Youngstown	11/20	0 (total)		8 (total)			
Puerto Rico:	Guaynabo	9/16–9/29	0 (total)		5 (total)			
	Loiza	9/16–9/29	0 (total)		4 (total)			
	Trujillo-Alto	9/16–9/29	0 (total)		4 (total)			
Tex:	Point Comfort	3/18	0	0	0	0		
	Corpus Christi	3/29	0	0	9	0		
		3/29	0	0	9	0		
	Ingleside	3/31	0	0	4	0		
Va:	Alexandria	3/12	0	0	4	0		
	Danville	2/3–2/17	0	0	3	0		
		2/3–2/17	0	0	0	0		
	Occuquan	3/25	0	0	8	0		
Virgin Islands:	Charlotte Amalie	9/1–9/14	0 (total)		0 (total)			
Wisc:	Ashland	4/23–5/6	0	0	5	0		
	Oshkosh	4/21–5/4	0	0	0	0		

[a] The minimum detectable radioactivity is 2 pCi/liter for strontium-90, gross alpha, and gross beta radioactivity; and 0.1 pCi/liter for radium-226. All values equal to or less than the minimum detectable radioactivity are reported as zero.

Table 2. Interstate carrier drinking water analysis program, 1970 summary

Radioactivity	Number of samples	Concentration[a] (pCi/liter)	
		Average	Range
Radium-226	3	1.3	0.3–2.1
Strontium-90	2	0	0
Gross alpha:			
Dissolved	19	.3	0–5
Suspended	19	0	0
Total sample	31	1.0	0–17
Gross beta:			
Dissolved	19	4.1	0–9
Suspended	19	0	0
Total sample	31	5.3	0–20

[a] The minimum detectable radioactivity is 2 pCi/liter for strontium-90, alpha, and beta radioactivity; and 0.1 pCi/liter for radium-226. All values equal to or less than the minimum detectable radioactivity are reported as zero.

Tritium Surveillance System, January-March 1971

Office of Radiation Programs
Environmental Protection Agency

The Tritium Surveillance System is an expansion of previous tritium surveillance activities conducted by the Office of Radiation Programs, Environmental Protection Agency (EPA). The principal effort in the past by the Office of Radiation Programs related to tritium releases has been the Tritium in Surface Water Network. This network was established in 1964, to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at surface water stations downstream from selected nuclear facilities. The network consisted of selected stations from existing water pollution sampling stations operated by the Office of Water Programs of EPA. The final data from this network for January–June 1970 were published previously (*1*).

Another effort of the Office of Radiation Programs was a tritium in precipitation program. This project was established in 1967 at selected Radiation Alert Network (RAN) stations covering the United States, including Alaska and Hawaii. The RAN is operated by the Office of Air Programs of EPA. The data from this project for July–December 1969, have been previously published (*2*). Due to the increased interest in tritium releases from nuclear facilities and the potential long-term accumulation in the environment, a

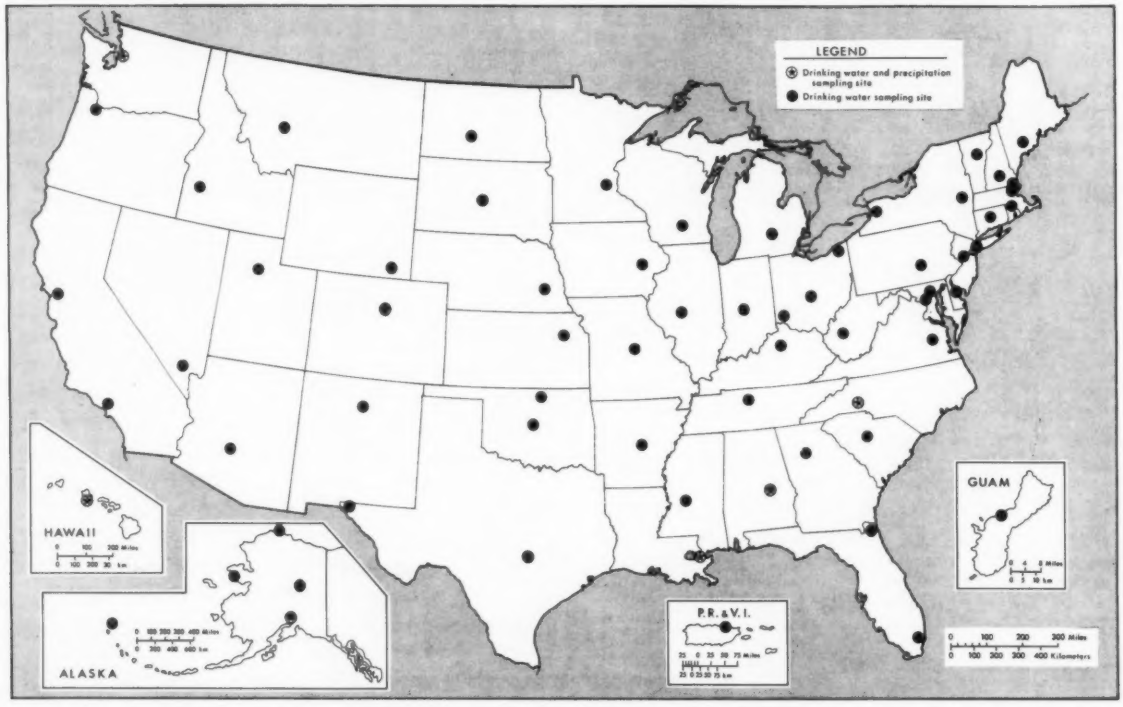

Figure 1. Drinking water and precipitation sampling locations for tritium surveillance system

national system was established to incorporate these projects or networks into one overall system.

Present network

The Tritium Surveillance System consists of 70 quarterly drinking water samples at the RAN stations, precipitation samples collected daily and analyzed monthly from 8 of the RAN stations (figure 1), and quarterly samples at 38 surface water stations (figure 2). The specific locations for the surface water sampling system were determined by examining the water drainage areas to assure that a representative sample from a large area or region was obtained and, if possible, incorporating several nuclear facility sites. All nuclear facilities that were operating, being constructed, or planned through 1975 were considered. Consideration was also given to the current surveillance programs of the States that will be involved in the collection of the samples. The surface water samples are collected quarterly, either downstream from a nuclear facility or at a background station.

The tap water samples are collected by the RAN operators on a quarterly basis. The precipitation samples are also collected by the RAN operators on a daily basis.

All samples are sent to one of the EPA laboratories for analysis. Due to the different sensitivity of procedures used by the three laboratories, the minimum detectable concentration varies. Analytical values which are not statistically significant at the 2-sigma confidence level have been reported as zero.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the RAN stations for January–March 1971. The average tritium concentration was 0.2 nCi/liter.

The radiation dose resulting from the observed tritium concentrations in the drinking water may be evaluated by using the relationship derived by Moghissi and Porter (*3*) from recommendations of the International Commission of Radiological Units and Measurements (*4*). Assuming that the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also that the specific activity of tritium

Table 1. Tritium concentration in tap water (RAN stations) January–March 1971

Location		Date collected (1971)	Tritium concentration (nCi/liter $\pm 2\sigma$)
Ala:	Montgomery	2/1	[a]0
Alaska:	Anchorage	3/1	.6±.4
	Attu Island	1/7	0
	Fairbanks	1/7	0
	Juneau	1/26	0
	Kodiak	1/5	.4±.4
	Nome	1/7	0
	Point Barrow	1/14	1.2±.4
Ariz:	Phoenix	NS	
Ark:	Little Rock	1/26	[a]0
Calif:	Berkeley	1/5	0
	Los Angeles	1/4	0
C.Z:	Ancon	2/16	[a]0
Colo:	Denver	2/11	1.0±.4
Conn:	Hartford	1/11	.5±.4
Del:	Dover	1/11	0
D.C:	Washington	1/5	[a]0
Fla:	Jacksonville	1/22	[a]0
	Miami	1/25	[a]0
Ga:	Atlanta	2/1	[a]0
Guam:	Agana	1/4	0
Hawaii:	Honolulu	1/11	0
Idaho:	Boise	1/7	0
Ill:	Springfield	1/10	0
Ind:	Indianapolis	1/14	0
Iowa:	Iowa City	1/25	.9±.4
Kans:	Topeka	1/13	0
Ky:	Frankfort	1/25	[a]0
La:	New Orleans	1/22	[a]0
Maine:	Augusta	1/5	0
Md:	Baltimore	1/25	[a]0
Mass:	Lawrence	1/5	0
	Winchester	1/5	0
Mich:	Lansing	2/5	0
Minn:	Minneapolis	1/5	1.0±.4
Miss:	Jackson	1/25	[a]0
Mo:	Jefferson City	1/5	0
Mont:	Helena	1/5	1.0±.4
Nebr:	Lincoln	1/6	0
Nev:	Las Vegas	1/6	0
N.H:	Concord	1/11	.5±.4
N.J:	Trenton	1/11	0
N. Mex:	Sante Fe	NS	
N.Y:	Albany	1/1	0
	Buffalo	1/11	0
	New York City	1/29	0
N.C:	Gastonia	1/26	[a]0
N. Dak:	Bismarck	2/8	1.1±.4
Ohio:	Cincinnati	1/22	0
	Columbus	1/5	0
	Painesville	1/5	0
Okla:	Oklahoma City	1/25	[a]0
	Ponca City	1/25	[a]0
Oreg:	Portland	NS	
Pa:	Harrisburg	1/5	0
P.R:	San Juan	2/18	[a]0
R.I:	Providence	1/6	0
S.C:	Columbia	1/8	[a]0
S. Dak:	Pierre	1/7	1.3±.4
Tenn:	Nashville	1/26	[a]0
Tex:	Austin	1/27	[a]0
	El Paso	1/26	[a]0
Utah:	Salt Lake City	1/4	.5±.4
Vt:	Barre	1/4	0
Va:	Richmond	1/31	[a]0
Wash:	Seattle	NS	
	Spokane	1/8	0
W. Va:	Charleston	1/28	[a]0
Wisc:	Madison	1/21	0
Wyo:	Cheyenne	1/4	1.7±.4
Network average			0.2

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero. For all other zero numbers and for the calculation of the network average, the minimum detection limit was 0.4 nCi/liter and all values equal to or less than 0.4 nCi/liter have been reported as zero.

NS, no sample.

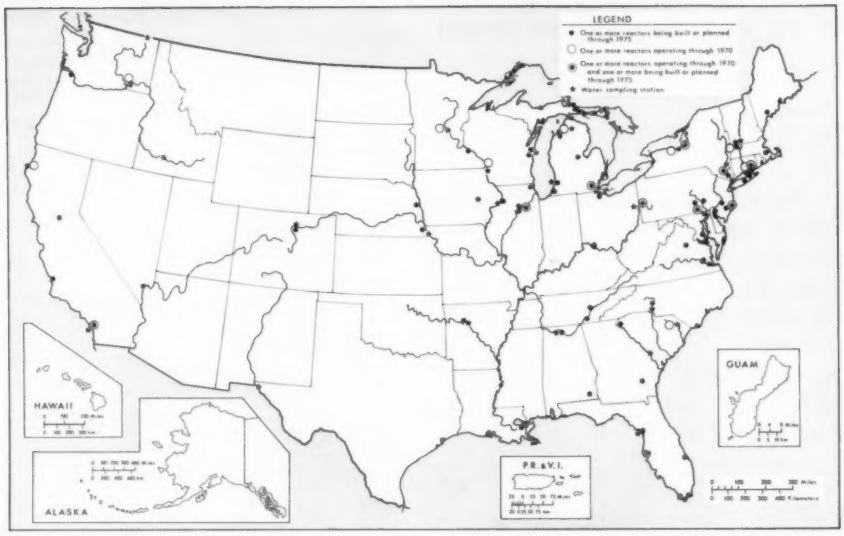

Figure 2. Surface water sampling locations for tritium surveillance system

Table 2. Tritium concentration in surface water, January–March 1971

Location		Water source	Facility	Collection date (1971)	Concentration (nCi/liter ±2σ)
Ala:	Decatur	Tennessee River	Browns Ferry	1/14	[a]0
Ark:	Morrilton	Arkansas River	Arkansas Nuclear	1/14	[a]0
Calif:	Eureka	Humboldt Bay	Humboldt Bay	1/28	0
	San Onofre	Pacific Ocean	San Onofre	3/4	0
Colo:	Greely	South Platte River	Fort St. Vrain	2/12	1.0±.4
Conn:	East Haddam	Connecticut River	Connecticut Yankee & Vermont Yankee	1/28	.6±.4
	Waterford	Long Island Sound	Millstone	1/28	.5±.4
Fla:	Crystal River	Gulf of Mexico	Crystal River	1/12	[a]0
	Key Largo	Biscayne Bay	Turkey Point	1/17	.3±.2
Idaho:	Buhl	Snake River	National Reactor Testing Station	1/7	0
Ill:	Moline	Mississippi River	Quad-Cities	1/29	0
	Morris	Illinois River	Dresden and Argonne	1/19	0
La:	New Orleans	Mississippi River	(Several)	1/14	[a]0
Md:	Conowingo	Susquehanna River	Peach Bottom and Three Mile Island	2/17	0
	Lusby	Chesapeake Bay	Calvert Cliffs	NS	
Mass:	Rowe	Deerfield River	Yankee	1/25	2.9±.4
Mich:	Charlevoix	Lake Michigan	Big Rock Point	3/21	0
	Monroe	Lake Erie	Enrico Fermi	3/15	0
	South Haven	Lake Michigan	Palisades	3/22	0
Minn:	Monticello	Mississippi River	Monticello	1/5	1.0±.4
Nebr:	Rulo	Missouri River	Fort Calhoun and Cooper	1/20	1.3±.4
Nev:	Boulder City	Colorado River	Background	NS	
N.J:	Bayside	Delaware River	Salem	NS	
N.Y:	Ossining	Hudson River	Indian Point	1/18	0
	Oswego	Lake Ontario	Nine Mile Point and R. E. Ginna	3/12	0
	Poughkeepsie	Hudson River	Background	1/13	0
N.C:	Charlotte	Catawba River	Wm. B. McGuire	1/14	[a]0
S.C:	Allendale	Savannah River	Savannah River Plant and Oconee	1/27	2.4±.2
	Hartsville	Lake Robinson	H. B. Robinson	3/10	.3±.2
Tenn:	Kingston	Clinch River	Oak Ridge	1/12	3.7±.2
Tex:	El Paso	Rio Grande	Los Alamos	1/11	.4±.4
Vt:	Vernon	Connecticut River	Vermont Yankee	1/4	.6±.4
Va:	Surry	James River	Surry	1/22	[a]0
Wash:	Northport	Columbia River	Background	2/10	.8±.4
	Pasco	Columbia River	Hanford	1/15	.9±.4
W.Va:	Wheeling	Ohio River	Shippingport	1/7	.5±.4
Wisc:	Two Creeks	Lake Michigan	Point Beach and Kewaunee	1/15	0
	Victory	Mississippi River	LaCrosse and Prairie Island	3/11	0
Network average					0.5

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero. For all other zero numbers and for the calculation of the network average, the minimum detection limit was 0.4 nCi/liter and all values equal to or less than 0.4 nCi/liter have been reported as zero.
NS, no sample.

in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in the drinking water was 1.7 nCi/liter during the first quarter. This corresponds to a dose of 0.3 mrem/a, or less than 0.2 percent of the Federal Radiation Council's Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed population.

The tritium concentrations for the surface water samples are given in table 2. The highest tritium concentration was 3.7 nCi/liter for the first quarter. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, this concentration corresponds to a dose of 0.6 mrem/a, or 0.4 percent of the Radiation Protection Guide.

The monthly analyses for tritium in precipitation samples at the eight RAN stations are shown in table 3.

Other coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1970	May 1971

Table 3. Tritium concentrations in precipitation from RAN stations, January–March 1971

Location	Tritium concentration[a] (nCi/liter ± 2σ)		
	January	February	March
Alaska: Anchorage	NS	0.4 ±0.2	0.5 ±0.2
Ala: Montgomery	0	0	0
Colo: Denver	0	.5± .2	.8± .2
Hawaii: Honolulu	0	0	.2± .2
La: New Orleans	0	0	0
N.C: Gastonia	0	0	0
Tex: Austin	NS	NS	NS
Wash: Seattle	0	0	.3± .2

[a] The minimum detection limit for these samples was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
NS, no sample.

REFERENCES

(1) BUREAU OF RADIOLOGICAL HEALTH. Tritium in surface water network, January–June 1970. Radiol Health Data Rep 11:638–639 (November 1970).

(2) BUREAU OF RADIOLOGICAL HEALTH. Tritium in precipitation (RAN), July–December 1969. Radiol Health Data Rep 11:354–355 (July 1970).

(3) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

(4) INTERNATIONAL COMMISSION OF RADIOLOGICAL UNITS AND MEASUREMENTS. Recommendations of the International Commission of Radiological Units and Measurements, National Bureau of Standards Handbook 85 (1964).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	July–December 1970	June 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1968	April 1971

1. Radiation Alert Network March 1971

Office of Air Programs
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the short-lived radon daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Office of Air Programs, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during March 1971. All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Precipitation			
							Total depth (mm)	Field estimation of deposition		
			Maximum	Minimum	Average[a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	23	3	0	1	9	456	9	456	186
Alaska:	Anchorage	3	0	0	0	0				
	Attu Island	24	0	0	0	0				
	Fairbanks	0				0				
	Juneau	7	16	1	3	2	15	2	15	0
	Kodiak	12	0	0	0	0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	12	9	2	4	0				
Ark:	Little Rock	13	2	0	0	0				
Calif:	Berkeley	23	1	0	0	4	72	4	72	0
	Los Angeles	23	4	0	1	0				
C.Z:	Ancon	5	0	0	0	0				
Colo:	Denver	23	7	1	2	2	25	[b]		
Conn:	Hartford	23	0	0	0	7	91	7	91	4
Del:	Dover	23	1	0	0	0				
D.C:	Washington	27	1	0	0	0				
Fla:	Jacksonville	22	2	0	1	4	68	4	68	13
	Miami	21	1	0	0	0				
Ga:	Atlanta	20	2	1	1	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	26	1	0	0	5	76	[b]		
Idaho:	Boise	22	2	0	1	7	41	7	41	5
Ill:	Sprinfigeld	4	1	0	1	0				
Ind:	Indianapolis	22	1	0	0	0				
Iowa:	Iowa City	20	3	0	0	3	10	3	10	3
Kans:	Topeka	23	3	0	1	3	17	3	17	1
Ky:	Frankfort	0				0				
La:	New Orleans	20	1	0	0	9	133	[b]		
Maine:	Augusta	23	1	0	0	6	88	6	88	3
Md:	Baltimore	22	2	0	0	5	40	5	40	0
Mass:	Lawrence	23	1	0	0	4	45	4	45	0
	Winchester	23	1	0	0	7	70	7	70	0
Mich:	Lansing	21	1	0	0	0				
Minn:	Minneapolis	23	1	0	0	2	35	2	35	5
Miss:	Jackson	21	1	0	0	9	357	9	357	25
Mo:	Jefferson City	23	3	0	1	2	23	2	23	0
Mont:	Helena	21	2	0	1	1	3	1	3	3
Nebr:	Lincoln	22	5	0	1	3	66	3	66	39
Nev:	Las Vegas	21	4	0	2	0				
N.H:	Concord	0				0				
N.J:	Trenton	23	1	0	0	8	104	8	104	9
N.Mex:	Santa Fe	11	1	0	0	0				
N.Y:	Albany	15	0	0	0	4	25	4	25	12
	Buffalo	22	1	0	0	0				
	New York City	0				0				
N.C:	Gastonia	18	5	0	2	6	56	[b]		
N.Dak:	Bismarck	23	1	0	0	2	4	2	4	0
Ohio:	Cincinnati	0				0				
	Columbus	0				0				
	Painesville	23	1	0	1	7	31	7	31	7
Okla:	Oklahoma City	0				0				
	Ponca City	23	11	0	2	0				
Oreg:	Portland	20	0	0	0	17	192	16	177	10
Pa:	Harrisburg	9	0	0	0	0				
P.R:	San Juan	0				0				
R.I:	Providence	20	1	0	0	0				
S.C:	Columbia	19	3	0	1	9	154	9	154	20
S.Dak:	Pierre	23	6	0	1	0				
Tenn:	Nashville	22	1	0	1	9	87	9	87	7
Tex:	Austin	0				0				
	El Paso	0				0				
Utah:	Salt Lake City	31	2	0	1	7	16	6	14	1
Vt:	Barre	0				0				
Va:	Richmond	22	1	0	0	7	71	7	71	45
Wash:	Seattle	10	0	0	0	10	138	[b]		
	Spokane	17	1	0	1	0				
W.Va:	Charleston	23	3	0	1	11	53	10	44	5
Wisc:	Madison	23	1	0	0	4	40	4	40	8
Wyo:	Cheyenne	23	4	0	1	3	25	3	25	1
Network summary		1,104	16	0	1	198	94	6	78	14

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program,[1] March 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for January 1971 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, March 1971

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	5	0.1	0.1	0.1	33	0.88
Coral Harbour	5	.1	.1	.1	111	.70
Edmonton	5	.2	.1	.2	26	.56
Ft. Churchill	4	.1	.1	.1	215	.44
Fredericton	5	.2	.0	.1	19	2.35
Goose Bay	5	.1	.0	.1	7	.89
Halifax	18	.3	.1	.2	53	6.98
Inuvik	5	.1	.1	.1	NA	NA
Montreal	5	.1	.1	.1	49	3.40
Moosonee	5	.2	.1	.1	26	.18
Ottawa	5	.2	.1	.1	29	1.98
Quebec	5	.2	.1	.1	12	1.13
Regina	5	.2	.1	.1	51	1.16
Resolute	5	.2	.1	.1	[a]33	[a].14
St. John's, Nfld	5	.2	.1	.1	86	8.08
Saskatoon	5	.1	.1	.1	29	.61
Sault Ste. Marie	5	.2	.1	.2	65	3.95
Thunder Bay	5	.2	.1	.1	65	3.53
Toronto	5	.1	.1	.1	75	2.93
Vancouver	5	.2	.1	.1	54	8.53
Whitehorse	5	.2	.1	.1	14	.15
Windsor	5	.1	.1	.1	33	1.61
Winnipeg	4	.1	.1	.1	53	2.32
Yellowknife	5	.1	.1	.1	22	.30
Network summary	131	0.3	0.0	0.1	50	2.30

[a] Analysis covers period from February 1 to March 31.
NA, no analysis.

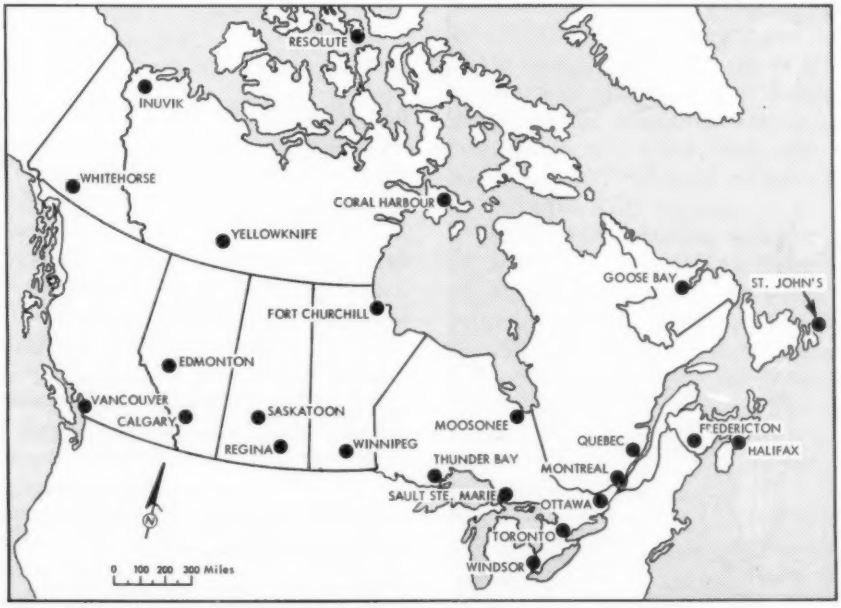

Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program March 1971

Pan American Health Organization and
Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The March 1971 air monitoring results from the participating countries are given in table 3.

Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, March 1971

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	NS			
Bolivia:	La Paz	18	0.09	0.00	0.03
Chile:	Santiago	30	.73	.05	.18
Colombia:	Bogota	22	.08	.01	.04
Ecuador:	Cuenca	NS			
	Guayaquil	NS			
	Quito	NS			
Guyana:	Georgetown	12	.63	.09	.25
Jamaica:	Kingston	NS			
Peru:	Lima	23	.16	.04	.08
Venezuela:	Caracas	5	.45	.14	.27
West Indies:	Trinidad	18	.80	.05	.37
Pan American summary		128	0.80	0.00	0.15

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).
(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).
(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).
(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).
(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

A summary of the environmental radioactivity data follows for the Savannah River Plant.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Savannah River Plant: January–June 1970

E. I. duPont de Nemours
Aiken, S.C.

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. duPont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Ga. Production facilities include a fuel preparation area, three reactors, two fuel separation areas, and a heavy water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

A continuous monitoring program has been maintained since 1951 (before plant startup) to determine the concentrations of radioactive materials in a 1,200 square-mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale counties in South Carolina, and Richmond, Burke, and Screven counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the AEC radiation protection standards as given in the AEC Manual.

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity and atmospheric fallout are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during January–June 1970.

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by biweekly analyses of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a

[2] Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, January–June 1970" (DPST-10-30-2).

circle of about a 25-mile radius from the center of the plant (figure 1). Deposition rates of radioactive material at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne radioactivity by SRP would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Ga., and at Columbia and Greenville, S.C., are so distant from SRP that the effect of SRP operations is negligible; they serve as reference points for determining background radioactivity levels (figure 2). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between fallout and SRP releases.

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fuel separation areas, was obscured by fallout. The influence of nuclear tests, which resumed in September 1961, is shown in figure 3. The present low levels of atmospheric activity are attributed to the moratorium on above-ground nuclear tests, which began in 1962. The observed spring increases are anticipated and result primarily from the mixing of the stratospheric debris into the troposphere. The average beta concentration in air increased from 0.15 pCi/m³ to 0.26 pCi/m³ during the first half of 1970. Gamma-emitting radionuclides in fallout were cesium-134, -137, cerium-141, -144, ruthenium-103, -106, and zirconium-niobium-95.

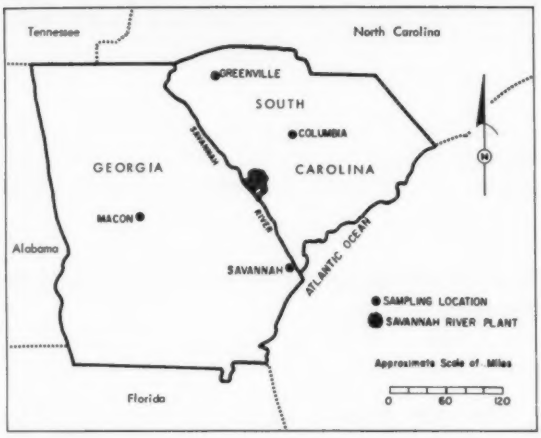

Figure 2. Distant air monitoring stations, Savannah River Plant

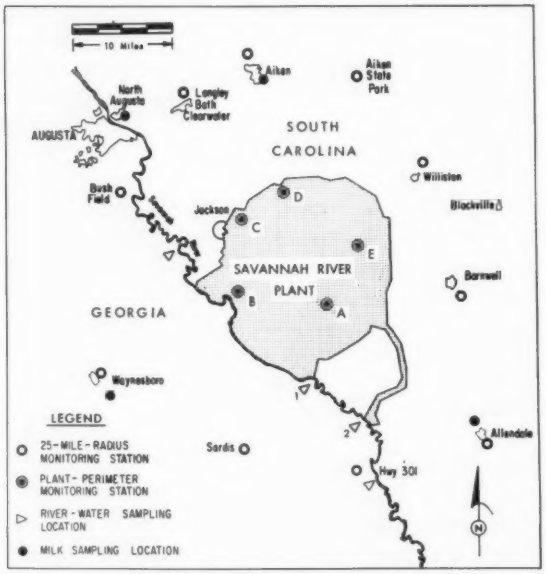

Figure 1. Environmental sampling locations, Savannah River Plant

Short radioactive half-life barium-lanthanum-140, neptunium-239, and iodine-131 in routine air samples were less than the level of detection throughout the period. The major component, beryllium-7, is a naturally occurring radionuclide formed by interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. Radioactivity in air, determined from filter analyses, is shown in table 1. The January-June 1970 concentrations of filterable beta radioactivity (0.26 pCi/m³) and alpha radioactivity (1.1 fCi/m³) in air were 0.26 and 1.6 percent of the respective AEC standards. Tritium oxide concentrations in air, at the plant perimeter and at the 25-mile stations, did not exceed 0.2 percent of the AEC standard.

Deposition of fallout during January–June 1970 averaged 13 nCi/m² at the plant perimeter locations and 12 nCi/m² at the 25-mile radius locations; comparable values for the last half of 1969 were 7 and 8 nCi/m² (excluding naturally occurring beryllium-7). Deposition at each sampling location is presented in table 2.

Table 1. Radioactivity in air, Savannah River Plant, January–June 1970

Sampling points	Alpha radioactivity[a] (fCi/m³)			Nonvolatile beta radioactivity[b] (pCi/m³)			Specific radionuclides in composite samples (pCi/m³)					
	Maximum	Minimum	Average	Maximum	Minimum	Average	$^{89,90}Sr$	^{137}Cs	$^{141,144}Ce$	$^{103,106}Ru$	^{95}Zr-Nb	^{7}Be
Plant perimeter:												
A	2.0	0.2	0.8	0.56	0.07	0.29						
B	2.4	.8	1.2	.55	.06	.28						
C	2.9	.5	1.0	.55	.04	.27	0.010	0.01	0.07	0.07	0.14	0.18
D	1.7	ND	.9	.55	.05	.28						
E	2.6	.6	1.0	.54	.06	.29						
Average			1.0			0.28						
25-mile radius:												
Aiken Airport	2.4	.5	1.1	.53	.05	.27						
Aiken State Park	5.0	ND	1.6	.52	.05	.25						
Allendale	5.8	.4	1.7	.48	.04	.26						
Barnwell	4.4	.5	1.8	.49	.06	.26						
Bush Field	5.0	.3	1.8	.51	.04	.25	.013	.01	.06	.06	.12	.17
Langley	7.8	.6	2.4	.58	.05	.28						
Sardis	2.7	.3	1.4	.55	.04	.28						
Waynesboro	3.6	.4	1.9	.55	.05	.29						
Williston	4.2	.5	1.8	.47	.06	.25						
Highway 301	3.0	ND	1.5	.50	.05	.25						
Average			1.7			0.26						
Distant air-monitoring:												
S.C.												
Columbia	1.5	0.3	0.9	0.50	0.03	0.19						
Greenville	1.5	ND	.8	.56	.05	.28						
Ga.												
Macon	1.4	ND	.8	.91	.04	.26	.014	.01	.06	.05	.12	.17
Savannah	1.9	ND	.8	.54	.05	.27						
Average			0.8			0.25						

[a] AEC radiation protection standard-70 fCi/m³.
[b] AEC radiation protect on standard-100 pCi/m³.
ND, nondetectable

Table 2. Total fallout deposited, Savannah River Plant, January–June 1970

Sampling points	Radioactivity (nCi/m³)						
	Alpha[a]	Strontium-89	Strontium-90	Cesium-137	Cerium-141, 144	Zirconium-niobium-95	Beryllium-7[b]
Plant perimeter:							
A	3.4	1.7	0.7	1.3	5.8	9.6	19.1
B	2.5	.4	.5	.7	2.5	1.9	9.4
C	5.9	1.6	.5	.9	4.9	4.0	14.6
D	3.5	1.0	.5	1.1	5.8	7.3	23.7
E	4.5	1.3	.5	.9	4.2	5.1	11.3
Average	4.1	1.1	0.5	1.0	4.6	5.8	15.6
25-mile radius:							
Aiken Airport	2.7	1.3	.5	.9	4.0	4.9	19.3
Aiken State Park	3.3	.7	.7	.9	3.2	4.3	10.7
Allendale	2.6	1.1	1.0	1.0	5.0	6.1	17.5
Barnwell	1.7	.5	.3	.7	2.5	3.9	10.6
Bush Field	2.0	.4	.7	.9	4.6	6.4	15.8
Langley	5.3	1.7	.9	1.2	4.7	6.9	18.9
Sardis	3.4	1.2	.5	1.4	4.6	9.2	19.9
Waynesboro	3.8	1.6	.7	1.3	5.0	7.2	14.1
Williston	2.0	.8	.3	.7	2.0	3.2	9.8
Highway 301	3.3	1.5	.7	1.2	5.9	8.1	15.4
Average	3.0	1.1	0.7	1.0	3.7	6.1	15.2

[a] Multiple by 10^{-2}.
[b] A naturally-occurring radionuclide.

Water monitoring

The plant site is drained by five streams that flow several miles through the reservation before reaching the river (figure 4). The primary sources of the very small amount of radioactivity that reaches the river are the reactor facilities. The reactors are cooled and moderated by heavy water which, in turn, is cooled by river water in heat exchangers. This arrangement prevents irradia-

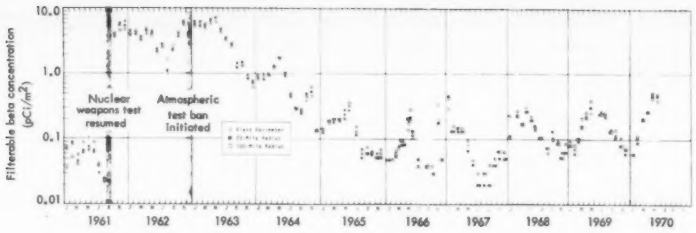

Figure 3. Influence of weapons tests

tion of the river water so that radioactivity is discharged into the river water only on the rare occasions when small quantities of moderator are lost by heat-exchanger leaks.

The irradiated fuel (canned to prevent leaching of radionuclides) discharged from a reactor is stored in a large, water-filled basin that is purged to maintain clarity and to control water temperature. Newly discharged fuel is placed into an isolated section of the basin equipped with a water-

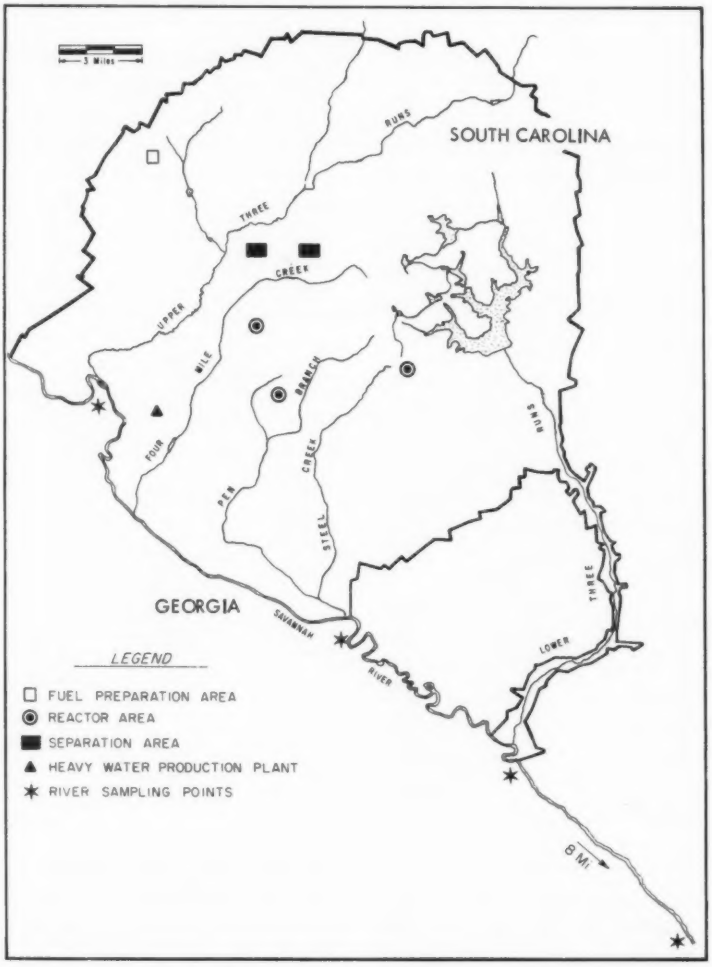

Figure 4. SRP production and effluent streams

circulating system. Portable filters and deionizers are provided to remove a large percentage of the radionuclides, and a heat exchanger is used to control basin water temperature. Tritium from the irradiation of the D_2O moderator accounts for the largest quantity of radioactivity released by the reactors to the environment. However, the contribution to the Savannah River results in concentrations less than 1 percent of the AEC standard.

In January 1965, the Beaufort-Jasper Water Authority began operation of a treatment facility to furnish sanitary water, partially supplied from the Savannah River, to most of Beaufort County, S.C. Water is supplied through a canal from the river at a location about 90 miles below the Savannah River Plant. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand. The tritium concentrations in raw water collected from the Beaufort-Jasper Water Plant averaged 1.7 nCi/liter (0.06 percent of the AEC standard) during January–June 1970. The annual radiation exposure of an individual in this population due to the consumption of 1.2 liters per day of water containing the very low concentration of tritium is 0.16 mrem, (this exposure may be compared with 20 mrem per year from natural potassium found in the body of all persons or with the 170 mrem per year specified by the Federal Radiation Council as the annual dose guide for members of the public).

Communities near the plant get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed in April. There was no evidence that SRP contributed radioactivity to drinking water supplies; concentrations of alpha radioactivity (1.1 pCi/liter) and beta radioactivity (6 pCi/liter) were essentially the same as those observed before plant startup. Radioactivity data in public water supplies are presented in table 3.

Table 3. Radioactivity in public water supplies January–June 1970

Sampling points	Alpha radioactivity[a] (pCi/liter)	Nonvolatile beta radioactivity[b] (pCi/liter)
	April	April
Aiken	0.9	ND
Allendale	.7	8
Augusta	.3	ND
Barnwell	.5	6
Bath	1.6	ND
Blackville	.2	ND
Clearwater	ND	ND
Jackson	6.8	18
Langley	1.3	ND
New Ellenton	.3	4
North Augusta	.3	ND
Sardis	.4	4
Waynesboro	.3	4
Williston	1.5	7
Average	1.1	6

[a] AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.
[b] AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.
ND, nondetectable.

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 4. Concentrations of alpha and nonvolatile beta radioactivity in river water for the past year are presented in table 4. Average concentrations of specific radionuclides found in river water during January–June 1970 appear in table 5.

Table 4. Radioactivity in Savannah River water, January–June 1970

Sampling point	Alpha radioactivity[a] (pCi/liter)				Nonvolatile beta radioactivity[b] (pCi/liter)			
	January–June 1970			July–December 1969	January–June 1970			July–December 1969
	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average
1 mile upstream from Upper Three Runs Creek (control)	0.5	ND	ND	ND	8	ND	ND	4
Downstream from Steel Creek	.4	ND	ND	ND	11	ND	4	6
Downstream from Lower Three Runs Creek	.4	ND	ND	ND	16	ND	8	8
8 miles downstream from Lower Three Runs Creek	.6	ND	ND	ND	15	ND	6	7

[a] AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.
[b] AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.
ND, nondetectable.

Table 5. Average concentration of radionuclides in Savannah River water, January–June 1970

Radionuclide	Concentration (pCi/liter)			
	Sensitivity of analysis	Control (1 mile upstream from Upper Three Runs Creek)	Highway 301 (8 miles downstream from Lower Three Runs Creek)	Percent AEC standard at Highway 301
Tritium	600	750	5,800	0.19
Ruthenium-103, -106	3.2	ND	ND	<.03
Cerium-141, -144	2.5	ND	ND	<.02
Cesium-134, -137	.6	ND	.5	.008
Neptunium-239	2.2	ND	ND	<.002
Barium-lanthanum-140	1.6	ND	ND	<.01
Zirconium-niobium-95	.5	ND	ND	<.001
Chromium-51	4.3	ND	ND	<.001
Strontium-89	.3	ND	1.3	.04
Iodine-131	.2	ND	ND	<.07
Strontium-90	.01	.7	1.1	.37
Cobalt-60	1.4	ND	ND	<.005
Zinc-65	1.1	ND	ND	<.001
Manganese-54	.4	ND	ND	<.0004
Sulfur-35	5.0	ND	5.8	.01

ND, nondetectable, less than sensitivity of analysis.

Tritium, sulfur-35, and trace amounts of cesium-137, strontium-89, and strontium-90 were the radionuclides of SRP origin detectable in river water at the downstream location. Strontium-90 and tritium from worldwide fallout were also detected in river upstream from SRP effluents.

Tritium, a beta-particle emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy water moderator in the reactors. Tritium is among the least dangerous of all radionuclides because it does not concentrate in body tissues. The concentration of tritium in river water averaged 0.19 percent of the AEC standard.

Fish in Savannah River

Fish, predominantly bream, were collected weekly upstream, adjacent to, and downstream from the Savannah River Plant effluents. Specific radionuclide analyses of fish are summarized in table 6. The radioactivity in bone and flesh from fish collected adjacent to and downstream from SRP indicates some minor contribution by SRP. Although measurably higher than similar collections at the control station upstream from SRP effluents, the increase is of minor significance when referenced against intake guides defined by the AEC radiation protection standard.

Table 6. Radioactivity in Savannah River fish January–June 1970

Location	Type of sample[a]	Concentration (pCi/g wet weight)			
		Strontium-89, 90		Cesium-137	
		Maximum	Average	Maximum	Average
Above plant boundary (Control)	Bone	16	7	<2	<2
	Flesh	1	<1	<1	<1
Adjacent to plant	Bone	26	14	<2	<2
	Flesh	1	<1	3	2
Below plant at Highway 301	Bone	27	14	<2	<2
	Flesh	1	<1	2	2

[a] Monthly composites of weekly collections for strontium-89, -90 and cesium-137.

Vegetation

Radioactive contamination of growing plants may result from deposition on foliar surfaces or sorption of radioactive materials from the soil.

Grass samples were collected at seven locations along the plant perimeter and at seven other locations along a 25-mile radius route (these are not designated on figure 2). Bermuda grass was selected for analysis because of its importance as a

pasture grass for dairy herds and its availability during all seasons of the year. Samples from each quadrant of the plant site and of the surrounding area were composited for monthly analysis. Gamma-emitting radionuclides in grass samples (excluding beryllium-7) were from fallout. Alpha-particle emitters averaged 0.1 pCi/g at the plant perimeter and 0.2 pCi/g at the 25-mile radius locations as compared to 0.1 pCi/g during the last half of 1969; gamma-ray emitters averaged 17.0 and 23.0 pCi/g, respectively, as compared to 12.0 and 15.3 pCi/g for the last half of 1969. Radioactivity in grass samples is presented in table 7.

Table 7. Radioactivity on vegetation, SRP January–June 1970

Radionuclides[a]	Concentration (pCi/g dry weight)			
	Plant perimeter (7 locations)		25-mile radius (7 locations)	
	Maximum	Average	Maximum	Average
Alpha emitters	0.6	0.1	0.5	0.2
Cesium-137	1.5	.9	.9	.7
Cerium-141, -144	9.7	6.1	13.6	8.3
Ruthenium-103, -106	ND	ND	ND	ND
Beryllium-7	13.1	7.7	14.1	10.9
Iodine-131	ND	ND	ND	ND
Barium–lanthanum-140	ND	ND	ND	ND
Zirconium–niobium-95	4.2	2.3	5.8	3.1

[a] Sensitivity of analysis in pCi/g dry weight, alpha emitters 0.10; cesium-137, 0.3; cerium-141, -144, 1.0; ruthenium-103, 106, 1.4; beryllium-7, 3.0; iodine-131, 0.2; barium–lanthanum-140, 6.0; zirconium–niobium-95, 0.5.
ND, nondetectable.

Milk

Milk was sampled at three dairies within a 25-mile radius of the Savannah River Plant (figure 1). Samples, collected biweekly, were analyzed for tritium and radioiodine. Strontium-90 and cesium-137 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during January–June 1970 are shown in table 8.

Average concentrations of the radionuclides in milk were 11 pCi/liter of strontium-90 and 20 pCi/liter of cesium-137 compared to 9 pCi/liter of strontium-90 and 12 pCi/liter of cesium-137 during the last half of 1969. Iodine-131 was less than the sensitivity of the analysis (5 pCi/liter) throughout this period. These values are consistent with those reported by the U.S. Public Health Service for most sections of the United States. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level (882 pCi/liter) was 0.03 percent of the AEC standard for water.

Table 8. Radioactivity in milk from local dairies Savannah River Plant, January–June 1970

Distributing points	Tritium[a] (nCi/liter)			Strontium-90[b] (pCi/liter)		Cesium-137[c] (pCi/liter)	
	Maximum	Minimum	Average	March	June	March	June
Aiken	1	ND	0.4	9	12	14	21
North Augusta	2	ND	1.4	16	15	11	33
Waynesboro	2.2	ND	.8	8	NS	NS	12
Major distributors[d]	2.1	ND	.9	11	9	25	22

[a] Sensitivity of analysis—0.2 nCi/liter; AEC standard—3,000 nCi/liter.
[b] Sensitivity of analysis—1.0 pCi/liter; AEC standard—300 pCi/liter.
[c] Sensitivity of analysis—5.0 pCi/liter; AEC standard—20 nCi/liter.
[d] Milk produced in local dairies but sold by major distributors.
ND, nondetectable, less than sensitivity of analysis.
NS, no sample.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. The January–June 1970 data (table 9) are characteristic of measurements observed at individual stations for the past several years.

Table 9. Environmental gamma radiation Savannah River Plant, January–June 1970

Sampling points	Gamma radiation (mR/24 h)		
	Maximum	Minimum	Average
Plant perimeter:			
A	0.28	0.18	0.22
B	.22	.13	.17
C	.27	.15	.18
D	.26	.14	.18
E	.25	.14	.17
Average			0.18
25-mile radius:			
Aiken Airport	0.21	0.13	0.16
Aiken State Park	.19	.12	.15
Allendale	.23	.13	.18
Barnwell	.38	.17	.21
Bush Field	.27	.18	.21
Langley	.41	.13	.22
Sardis	.20	.14	.18
Waynesboro	.21	.12	.16
Williston	.24	.17	.20
Highway 301	.27	.17	.22
Average			0.19

Summary

The quantity of radioactive waste released by the Savannah River Plant to its environs was, for the most part, too small to be distinguished from natural background radiation or was obscured by fallout from offsite sources. Beta radioactivity in air, which had no relationship to plant operations, was 1.7 times that observed during 1969. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. The average concentration of any radionuclide in river water at Highway 301 did not exceed 0.4 percent of the AEC radiation protection standard.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1969	May 1970
July–December 1969	December 1970

Reported Nuclear Detonations, June 1971

(Includes seismic signals presumably from foreign nuclear detonations)

The U.S. Atomic Energy Commission announced that on June 6, 1971, the United States recorded seismic signals, presumably from a Soviet underground explosion. The signals, which originated in the Semipalatinsk nuclear test area, were equivalent to those of an underground nuclear explosion in the low-intermediate yield range (20–200 kilotons TNT equivalent).

Underground nuclear testing at the Nevada Test Site resumed Wednesday, June 16, 1971. A nuclear test in the yield range of less than 20 kilotons was conducted underground by the Atomic Energy Commission at its Nevada Test Site. This test was the first since December 18, 1970.

On June 19, 1971, the United States recorded seismic signals presumably from a Soviet underground nuclear explosion. The signals originated in the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20–200 kilotons.

The U.S. Atomic Energy Commission conducted two underground nuclear tests at its Nevada Test Site on June 23 and 24, 1971. Both were in the low-intermediate yield range (20 to 200 kilotons TNT equivalent).

Seismic signals were recorded by the United States on June 29, 1971, presumably from a Soviet underground nuclear explosion. The signals originated in the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear test in the low-intermediate yield range of 20 to 200 kilotons.

CORRIGENDUM

In the January 1971 issue of *Radiological Health Data and Reports*, a corrigendum occurs in the third paragraph of the article, Reported Nuclear Detonations, December 1970. The date should be corrected in the second line, third paragraph and should read, "the test of December *18*, 1970. Radioactivity..." not December 16 as printed.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

Report of the Venting of the December 18, 1970, Underground Nuclear Detonation

The following report was summarized from the U.S. Atomic Energy Commission's news release of May 14, 1971, as it was deemed of interest to our readers. An investigation was conducted by a committee of technical experts (appointed by the U.S. Atomic Energy Commission) to determine the cause of an accidental release of radioactive material in the test of December 18, 1970.

The first AEC news release of December 18, 1970,[1] stated that a nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted underground by the Atomic Energy Commission at its Nevada Test Site. Radioactivity at very low levels (less than 1 milliroentgen per hour at populated locations) was recorded on the ground along State Highway 25, north of the test site (figure 1). Monitors and aircraft of the Environmental Protion Agency (formerly the U.S. Public Health Service) monitored the situation continuously. The radioactive air mass moved slowly north and northwest, widening gradually as it moved. Aircraft kept the air mass defined and instruments recorded levels of a few milliroentgens per hour several thousand feet above the ground. None of the readings indicated that there would be a health hazard to persons living downwind.

The committee which investigated the venting was composed of Dr. Wendell Weart of Sandia Laboratories, Albuquerque, N. Mex., Chairman; Dr. Lawrence S. Germain of the Lawrence Radiation Laboratory at Livermore, Calif.; and Dr. Robert R. Brownlee of the Los Alamos Scientific Laboratory, Los Alamos, N. Mex. The findings of this investigative group, which reported to the Manager, Nevada Operations Office, AEC, were endorsed by members of the Manager's Safety Panel of Consultants on Underground Testing.

The committee determined that the venting of the test—named Baneberry—was caused primarily by the earth around the explosive device being more highly saturated with water than had been anticipated. Baneberry was detonated at a depth

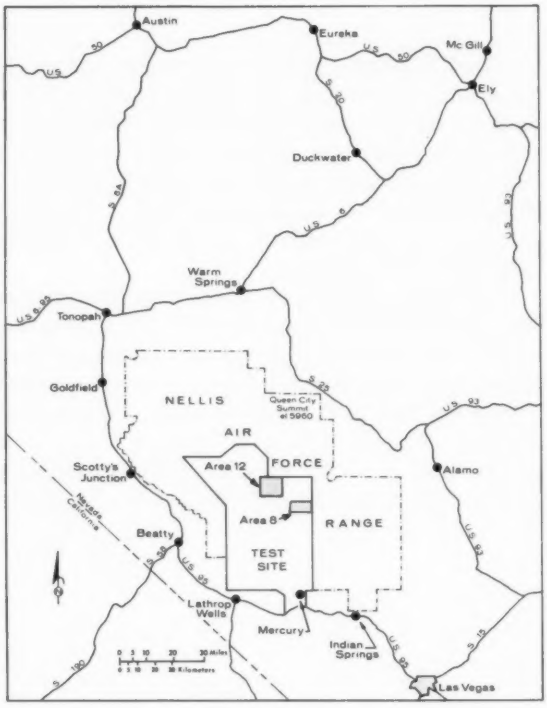

Figure 1. Nevada Test Site and vicinity

of 910 feet in an area of the test site where two other tests (with no problems) had been conducted previously.

The group concluded that the primary cause of venting in the Baneberry test was an unexpected and abnormally high water content (not associated with and well above the normal water table) at an unusually shallow depth in the earth surrounding the detonation point. This increased the coupling of energy into the earth, causing greater than expected close-in ground motions, and creating a crack from the explosion zone to the surface which permitted radioactivity to escape. The nature of the release is what could be expected from an underburied test. Had the same test occurred in the more usual test environment, without the high water content, it would have been

[1] Incorrectly reported in the January 1971 issue of *Radiological Health Data and Reports*, p. 80, as December 16, 1970.

contained satisfactorily underground. No preexisting faultline or crack was identified during the study as coinciding with the fissure through which venting occurred.

Pressures in the cavity created by the explosion lasted longer than normally, principally because of large amounts of water in the surrounding earth. The pressure forced gas through the ground to the surface, where a fissure opened along a line starting at about 60 feet from the surface zero point and extending a total distance of about 315 feet.

As is usual in such tests, the ceiling of the cavity formed underground by the explosion collapsed all the way to the surface in about 16 minutes, forming a saucer-like subsidence. Unlike most previous ventings, the Baneberry collapse did not entirely seal off pathways between the explosion zone and the surface, and radioactive gases continued to be emitted for some hours, in small quantities after the first venting.

Secondary phenomena which may have contributed to the venting include the following. The alluvium above the point of the explosion was of a harder, more consolidated variety than is usually encountered. The region underlying the alluvium is complex in structure, consisting of absorbing clay containing an unusual amount of water.

Nuclear explosive test devices have a range of yields (or amount of explosive force) which is calculated by the design laboratory, in this case, the Lawrence Radiation Laboratory at Livermore, Calif. In the case of the Baneberry test, it has been concluded after careful study that the yield of less than 20 kilotons was essentially as predicted and was not a factor in the venting.

In the case of Baneberry, there was a "line-of-sight pipe" running vertically from near the explosive device to the surface above ground zero. Such pipes, with almost all air evacuated to form a near-vacuum, have been used frequently in association with nuclear tests to obtain scientific data not obtainable in other ways. Various fast closure systems are used in sequence in the pipe to prevent radioactive debris from reaching the surface.

The Baneberry line-of-sight pipe performed as its designers intended, and there is no indication that the pipe had any primary role in the venting.

Baneberry was detonated in a drilled hole with a diameter of 86 inches. It was an uncased hole; that is, the explosive and instrument cannister and the line-of-sight pipe were placed in the hole as drilled. Frequently, a steel casing is used to prevent caving-in of earth and to provide a smooth interior surface for lowering the required packages without hindrance. Many tests involving no venting have been conducted using both cased and uncased holes. There is no evidence that the use of an uncased hole in the Baneberry test contributed in any way to the venting.

Baneberry was sited in Area 8 near the northern boundary of the Yucca Basin of the test site (figure 1). Two previous nuclear tests, one about 2,100 feet north-northeast and the other about 2,000 feet east of the Baneberry site, had presented no problems. However, the drilling history of the Baneberry site indicates a somewhat different geology than in the other two nearby test holes.

During the hole drilling, there was considerable sloughing or caving-in of earth in the lower portion of the hole, and this was overcome by the introduction of large quantities of cement to seal off the loose formations—a standard practice. Considerably more than usual water-absorbing clay was found in the formation, above and below the ultimate explosion point, which it turns out contributed to the problem. The detonation point was above the water table in the area, although all the underground formations in the area contain some water naturally.

Following Baneberry, some of the northern areas of the test site were closed because of residual radioactivity. The Area 12 camp has been reopened for occupancy and normal use, and work is progressing normally in all the areas of the test site. No exposure of onsite personnel exceeded the occupational guides set by the Federal Radiation Council (FRC).

In the offsite area also, all radiation exposures were within the FRC guidelines. The maximum estimated infinite external whole body dose was 0.036 rem to an adult at Clark Station north of the test site. This can be compared with the FRC guide for normal peacetime operations of 0.5 rem per year for an individual member of the public.

After the Western Environmental Research Laboratory (WERL) of the Environmental Protection Agency ended its environmental sampling program following the Baneberry venting, it was learned that in the area north of the Nevada Test Site where radioactivity had been measured,

sheepherders were using melted snow as a source of drinking and cooking water.

During the weeks following Baneberry, the sheepherders were in an area from about 30 miles east of Eureka, Nev., on U.S. Highway 50, south to Duckwater, Nev. Based on sampling results in the general area, on information obtained from the eight sheepherders about their location and water consumption, and on snowfall records, WERL estimates the dose to their thyroids from radioactive iodine at about 0.5 rads, plus or minus a factor of 3. The large uncertainty in the estimate results from the fact that there is no detailed information on radioactive contamination levels at the sheepherders' locations; on whether the old snowpack was diluted by new and uncontaminated snow; or about the distribution of the radioactivity at any depth in the snowpack.

For individual members of the general population, the Federal Radiation Council radiation protection guideline for thyroid dose is 1.5 rem per year.

Test resumption was approved under more stringent and detailed technical analysis and review procedures which evolved from the Baneberry investigation. These include a closer examination of the geology of test locations. This will include drilling added exploratory holes when necessary to enhance the understanding of the underground formations involved.

The Atomic Energy Commission has approved the resumption of underground nuclear testing at its Nevada Test Site following completion of an investigation of the cause of an accidental release of radioactive material in a test on December 18, 1970. There were no exposures to the public or workers above Federal Radiation Council guidelines.

☆ U.S. GOVERNMENT PRINTING OFFICE: – 436-635/12

SYNOPSES

Synopses of reports, incorporating list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

EVALUATION OF TELEVISION CONTRIBUTION TO THE ANNUAL GENETICALLY SIGNIFICANT RADIATION DOSE OF THE POPULATION. *X-Radiation Ad Hoc Committee, Electronic Industries Association. Radiological Health Data and Reports, Vol. 12,* July 1971, pp. 363-370.

The X-radiation Ad Hoc Committee of the Electronic Industries Association has used data from a U.S. Public Health Service survey of color television receivers in the Washington, D.C. area to estimate the annual genetically significant x-radiation dose to the U.S. population from television usage. Using these data and various assumptions, the annual genetically significant dose was estimated by the committee to be 0.5 mrem.

KEYWORDS: Color television receivers, genetic dose, U.S. population, Washington, D.C.

ORDER BLANK FOR RHD&R

To: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

Please enter my subscription for Radiological Health Data and Reports. I am enclosing Money Order ☐ Check☐ for this subscription. ($6.00 a year; $1.50 additional for foreign mailing.)

Please address RHD&R as follows._____

_____

_____

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 1971
For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Subscription price $6.00 a year, $1.50 additional for foreign mailing.
Price for a single copy of this issue is 50 cents.

July 1971

GUIDE FOR AUTHORS

The editorial staff invites reports and technical notes containing information related to radiological health. Proposed reports and notes should contain data and interpretations. All accepted manuscripts are subject to copy editing with approval of the author. The author is responsible for all statements made in his work.

Manuscripts are received with the understanding that other identical manuscripts are not under simultaneous consideration nor have appeared in any other publication.

The mission of *Radiological Health Data and Reports* is stated on the title page. It is suggested that authors read it for orientation of subject matter.

Submission of manuscripts

Send original and one legible copy of the paper, typed double-spaced on 8½ by 11-inch white bond with 1-inch margins.

Submitted manuscripts should be sent to Editor. Radiological Health Data and Reports, EPA, Office of Radiation Programs, Parklawn 18 B-40, Washington, D.C. 20460.

Preparation of manuscripts

The Government Printing Office style manual is used as a general guide in the preparation of all copy for *Radiological Health Data and Reports*. In addition, *Radiological Health Data and Reports* has developed a "Guide" regarding manuscript preparation which is available upon request. However, for most instances, past issues of *Radiological Health Data and Reports* would serve as a suitable guide in preparing manuscripts.

Titles, authors: Titles should be concise and informative enough to facilitate indexing. Names of authors should appear on the third line below the manuscript title. Affiliation of each author should be given by a brief footnote including titles, professional connections at the time of writing, present affiliation if different, and present address.

Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs whenever possible.

Illustrations: Glossy photographic prints or original illustrations suitable for reproduction which help enhance the understanding of the text should be included with the manuscript. Graphic materials should be of sufficient size so that lettering will be legible after reduction to printed page size (8½ by 6½ inches).

All illustrations should be numbered and each legend should be typed double-spaced on a separate sheet of paper. Legends should be brief and understandable without reference to text. The following information should be typed on a gummed label or adhesive strip and affixed to the back of each illustration: figure number, legend, and title of manuscript or name of senior author.

Tables: Tables should be self-explanatory and should supplement, not duplicate, the text. Each table should be typed on a separate sheet, double-spaced. All tables must be numbered consecutively beginning with 1, and each must have a title.

Equations: All equations must be typewritten, preferably containing symbols which are defined immediately below the equation. The definition of symbols should include the units of each term. Special symbols, such as Greek letters, may be printed carefully in the proper size, and exponents and subscripts should be clearly positioned. Mathematical notations should be simple, avoiding when feasible such complexities as fractions with fractions, subscripts with subscripts, etc.

Symbols and units: The use of internationally accepted units of measurements is preferred. A brief list of symbols and units commonly used in *Radiological Health Data and Reports* is given on the inside front cover of every issue and examples of most other matters of preferred usage may be found by examining recent issues. Isotope mass numbers are placed at the upper left of elements in long series or formulas, *e.g.*, ^{137}Cs; however, elements are spelled out in text and tables, with isotopes of the elements having a hyphen between element name and mass number; *e.g.*, strontium-90.

References: References should be typed on a separate sheet of paper.

Personal communications and unpublished data should not be included in the list of references. The following minimum data for each reference should be typed double-spaced: names of all authors in caps, complete title of article cited, name of journal abbreviated according to *Index Medicus*, volume number, first and last page numbers, month or week of issue, and year of publication. They should be arranged according to the order in which they are cited in the text, and not alphabetically. All references must be numbered consecutively.

Reprints

Contributors are ordinarily provided with 50 courtesy copies of the articles in the form of reprints. In cases of multiple authorship, additional copies will be provided for coauthors upon request.

ENVIRONMENTAL
PROTECTION AGENCY
OFFICE OF RADIATION PROGRAMS
WASHINGTON, D.C. 20460

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
ENVIRONMENTAL PROTECTION
AGENCY

Please CHECK if you do not desire to continue receiving this publication ☐; or, if a change of address is needed ☐ (indicate change, including zip code); tear off this cover and return to the above address.